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Quick et al.

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(45) **Date of Patent: Jun. 19, 2001**

(54) **PROCESS FOR MAKING AN ALLOY**

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(73) Assignee: **USF Filtration and Separations Group, Inc**, Timonium, MD (US)

(21) Appl. No.: **09/307,101**

(22) Filed: **May 7, 1999**

Related U.S. Application Data

(60) Provisional application No. 60/084,688, filed on May 8, 1998.

(51) **Int. Cl.**[7] **C22F 1/10**

(52) **U.S. Cl.** **148/676**; 420/590; 148/519; 428/680

(58) **Field of Search** 420/590; 148/519, 148/676; 428/680

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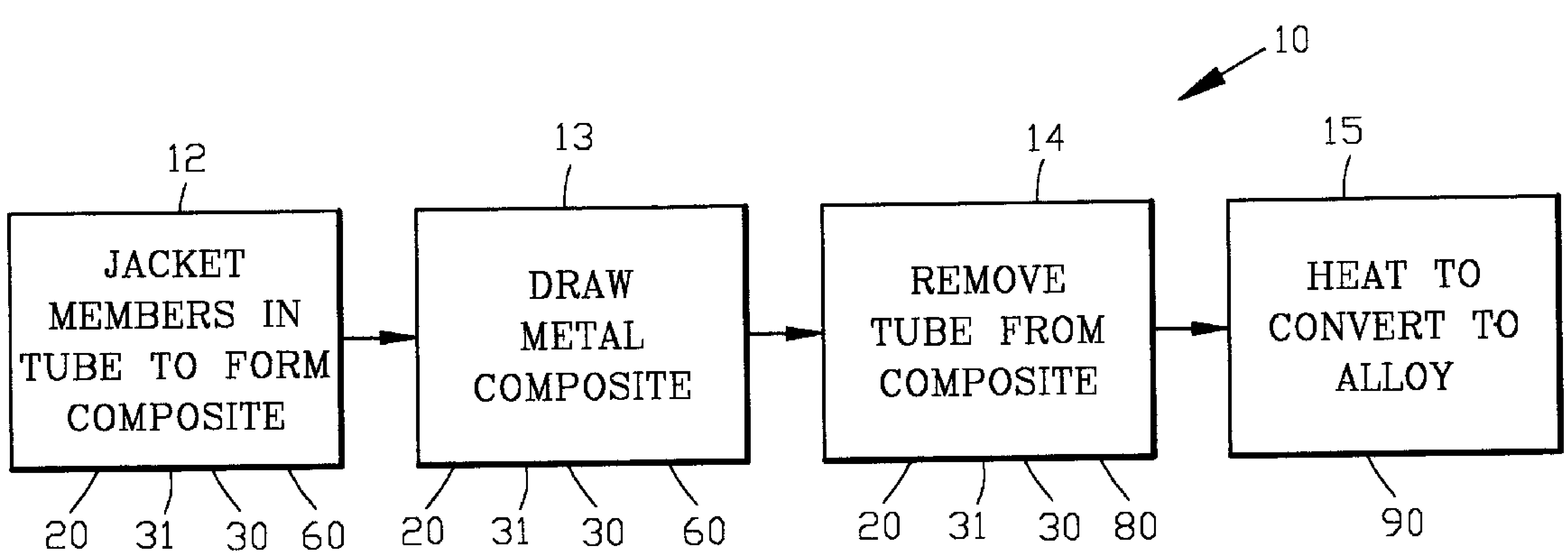
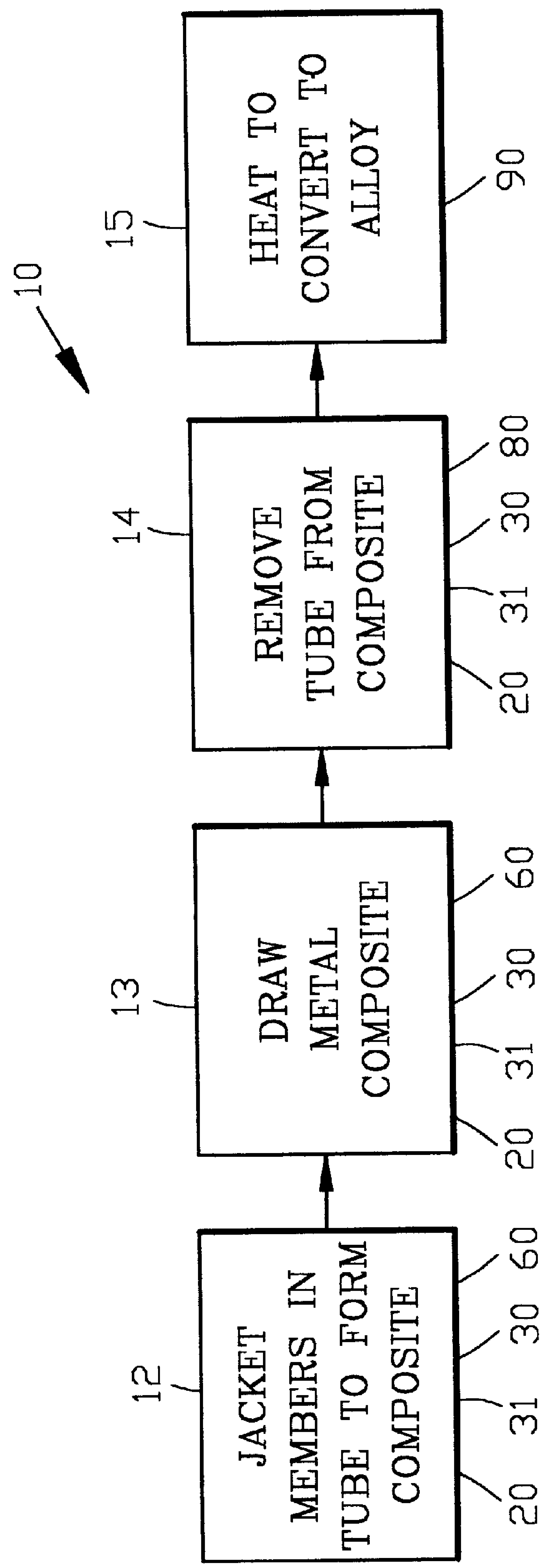
(57) **ABSTRACT**

A process is disclosed for making an alloy comprising the steps of cladding with a tube a plurality of metal members including a first and a second metal to form a metal composite. The metal composite is drawn for reducing the diameter thereof. The tube is removed to provide a remainder. The remainder is heated to convert the remainder to alloy. A multiplicity of composites may be processed simultaneously for producing fine alloy fibers.

18 Claims, 12 Drawing Sheets




JACKET MEMBERS IN TUBE TO FORM COMPOSITE
DRAW METAL COMPOSITE
REMOVE TUBE FROM COMPOSITE
HEAT TO CONVERT TO ALLOY
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12
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20
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31
60
80
90

FIG. 1

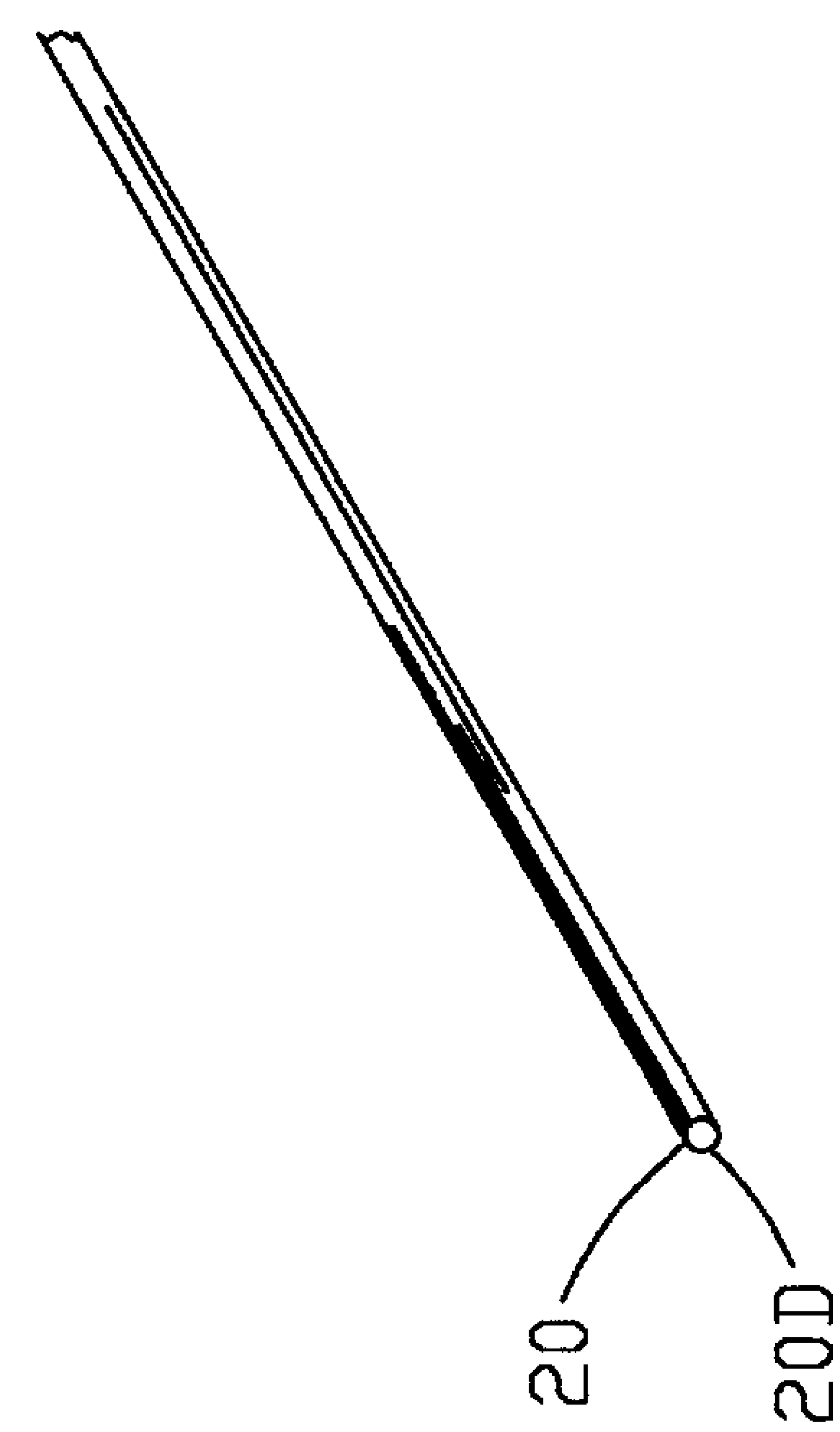


FIG. 2

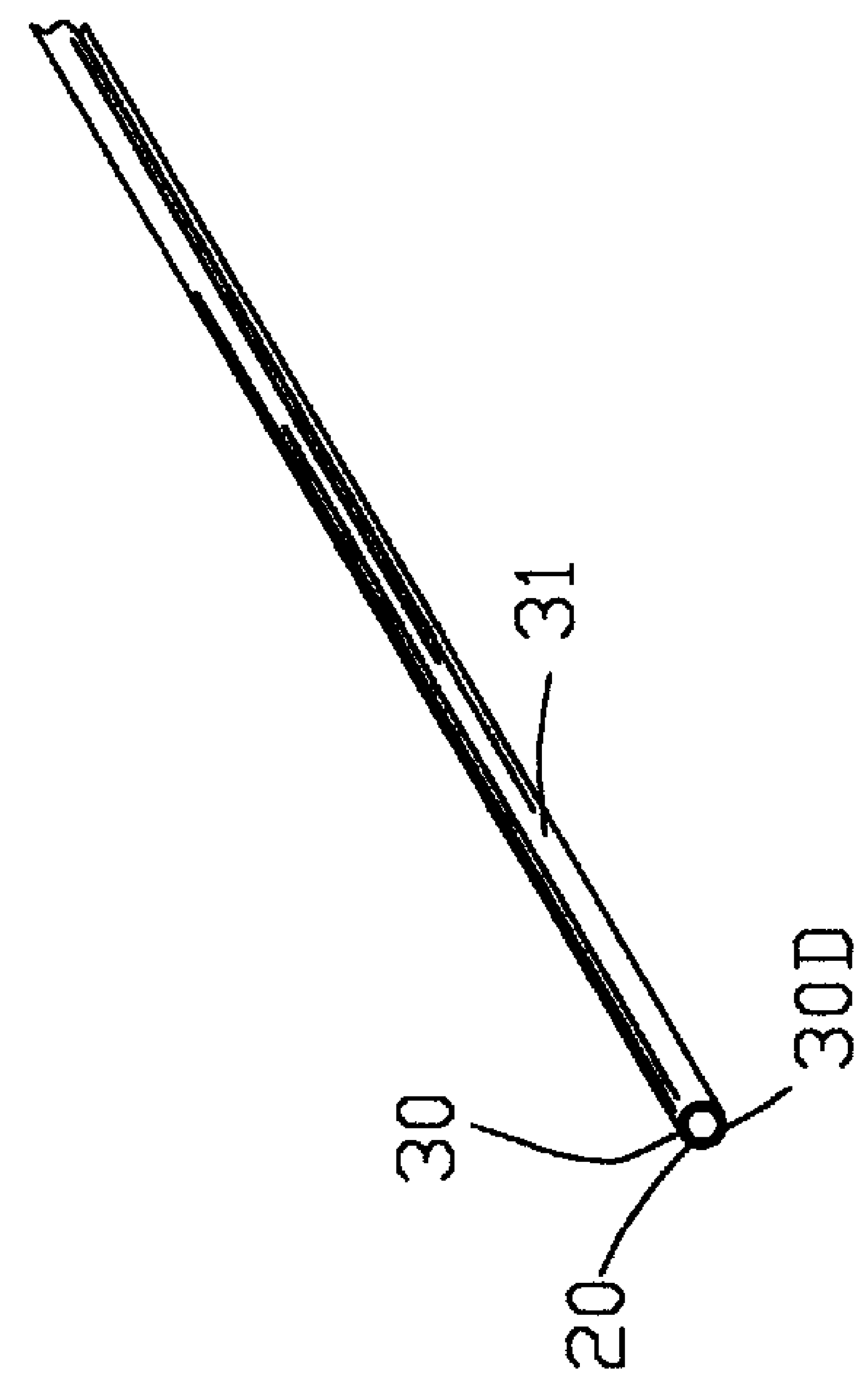


FIG. 3

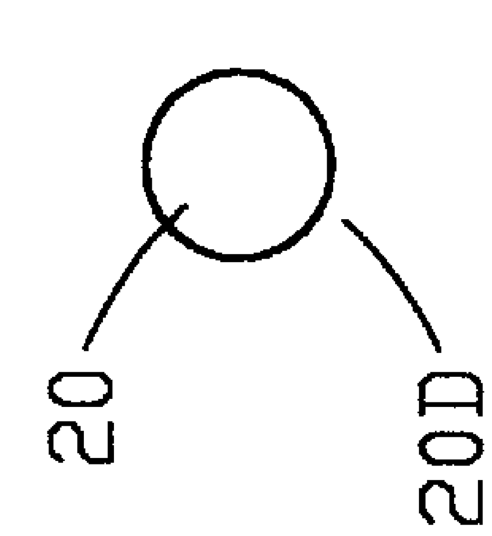


FIG. 2A

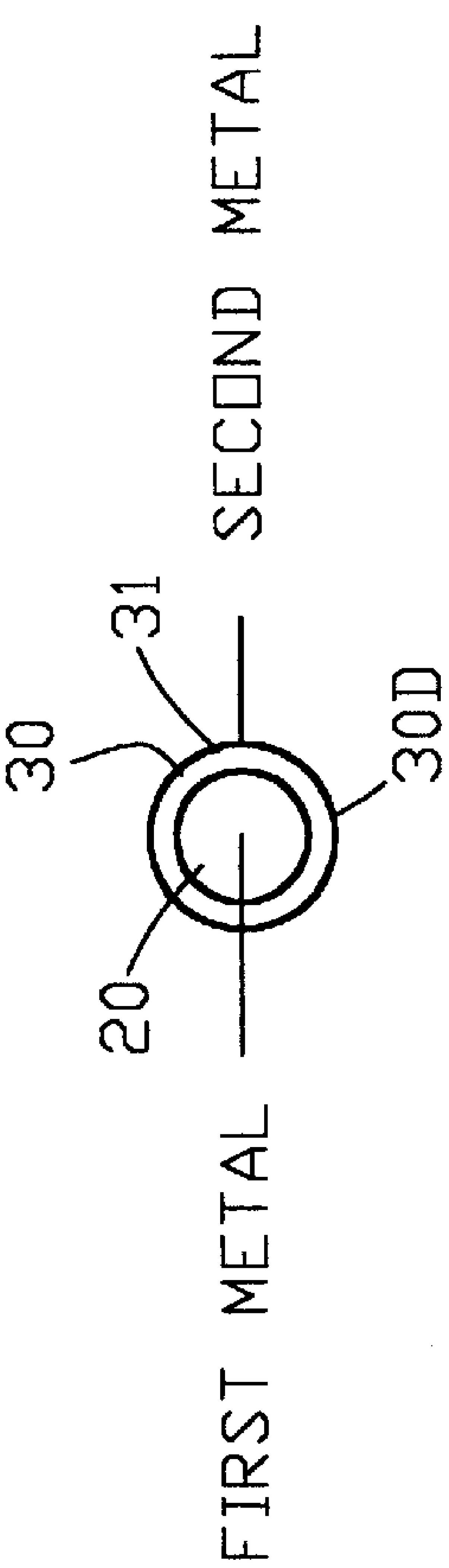


FIG. 3A

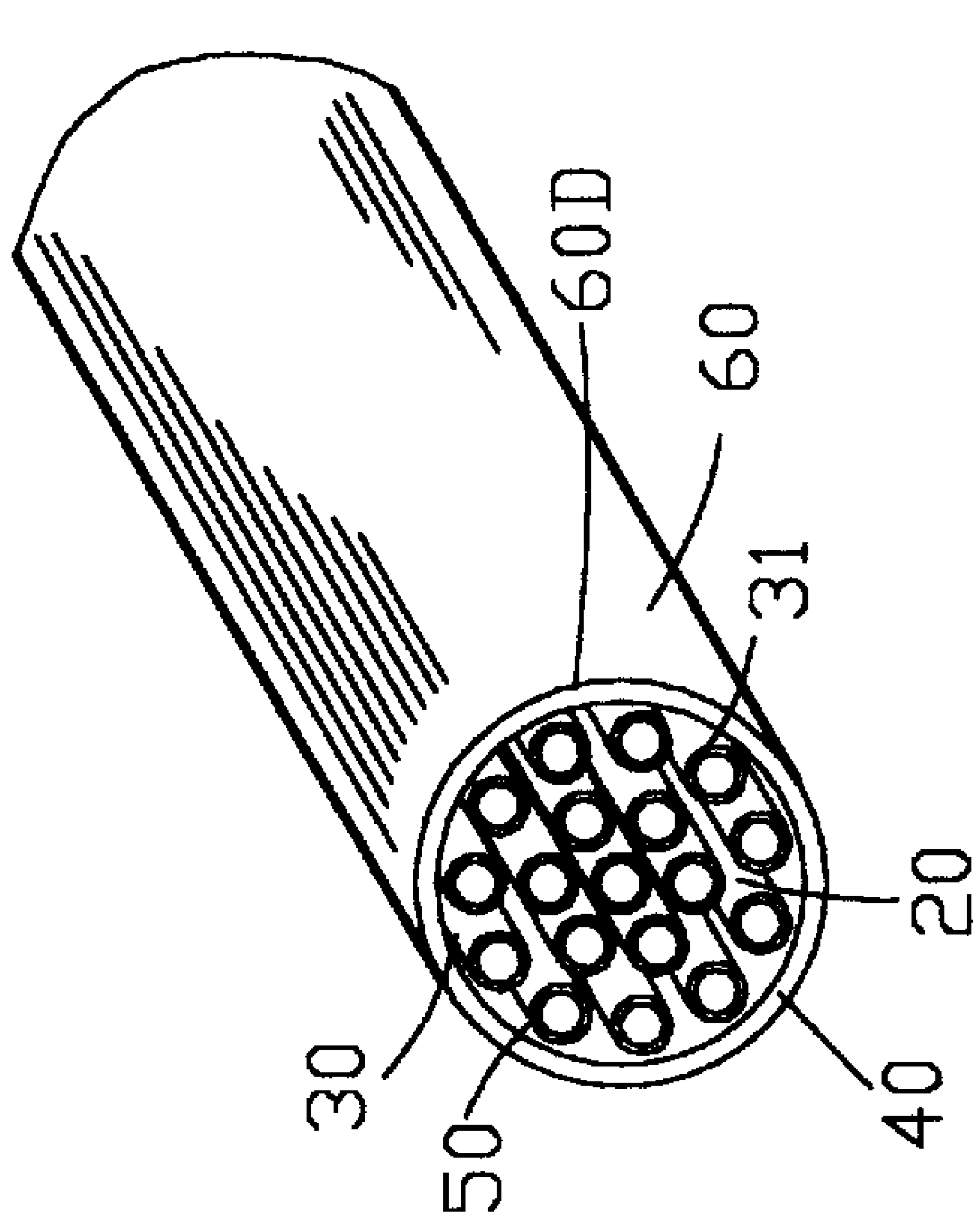


FIG. 4

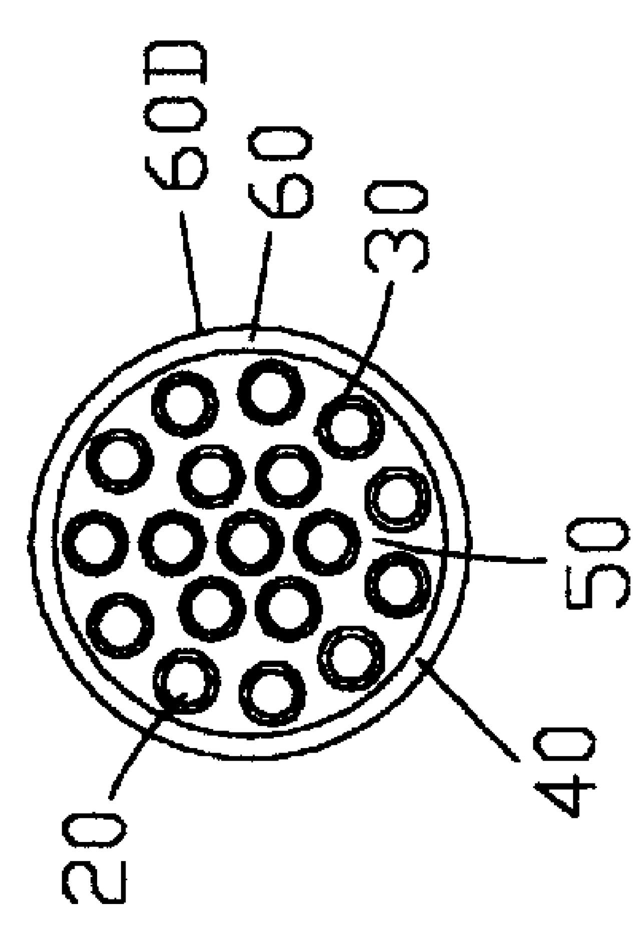


FIG. 4A

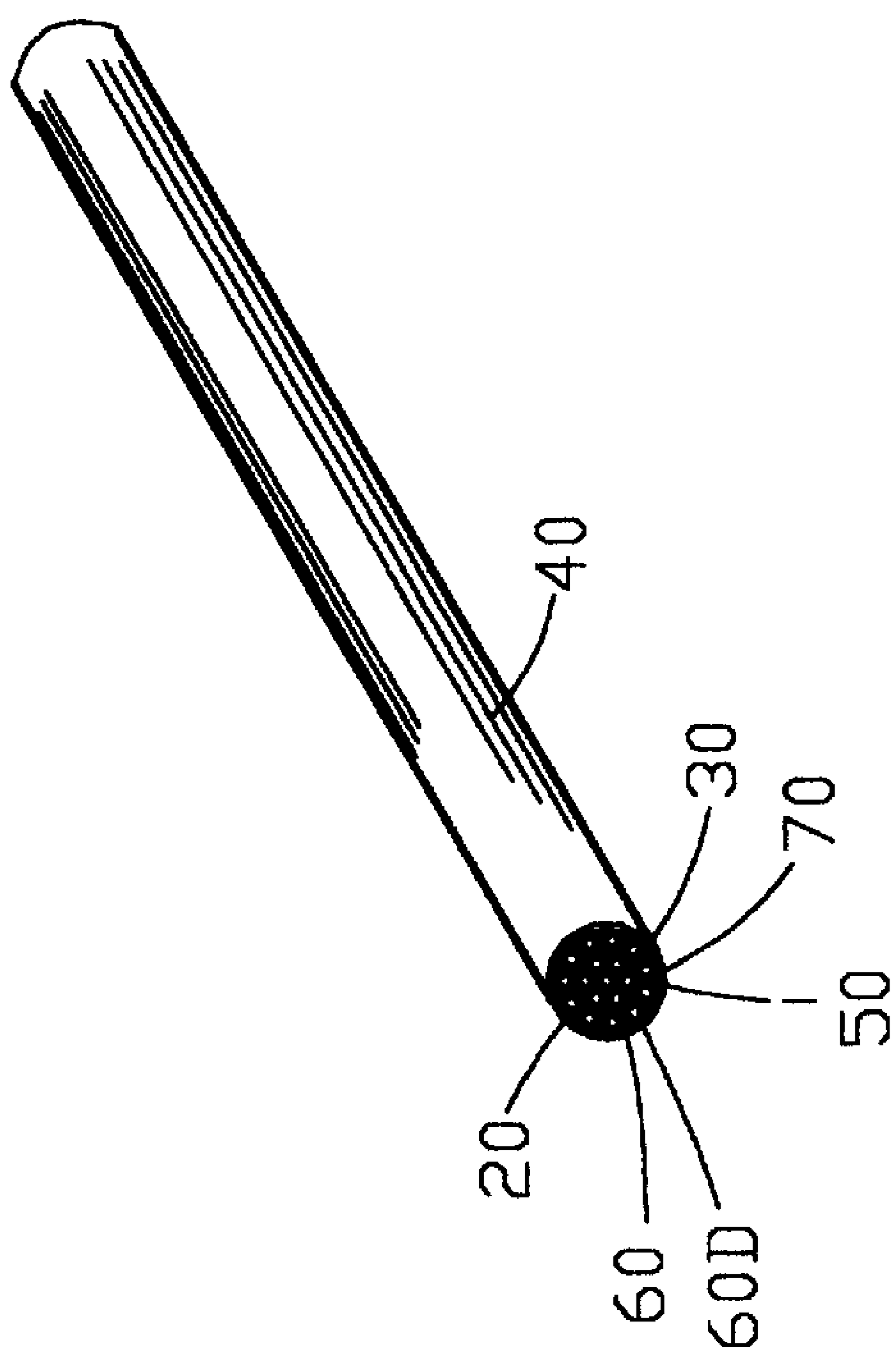


FIG. 5

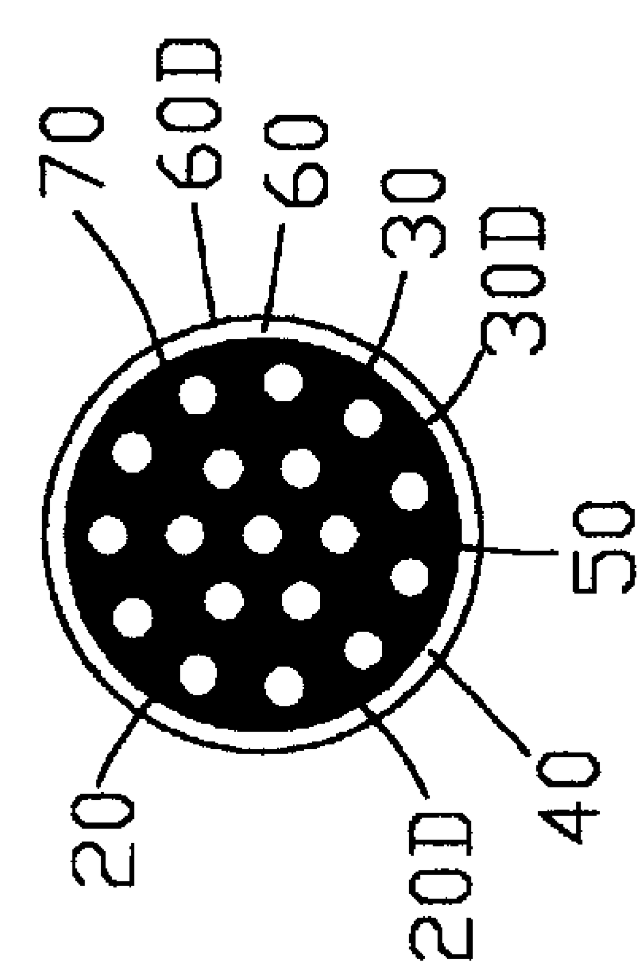


FIG. 5A

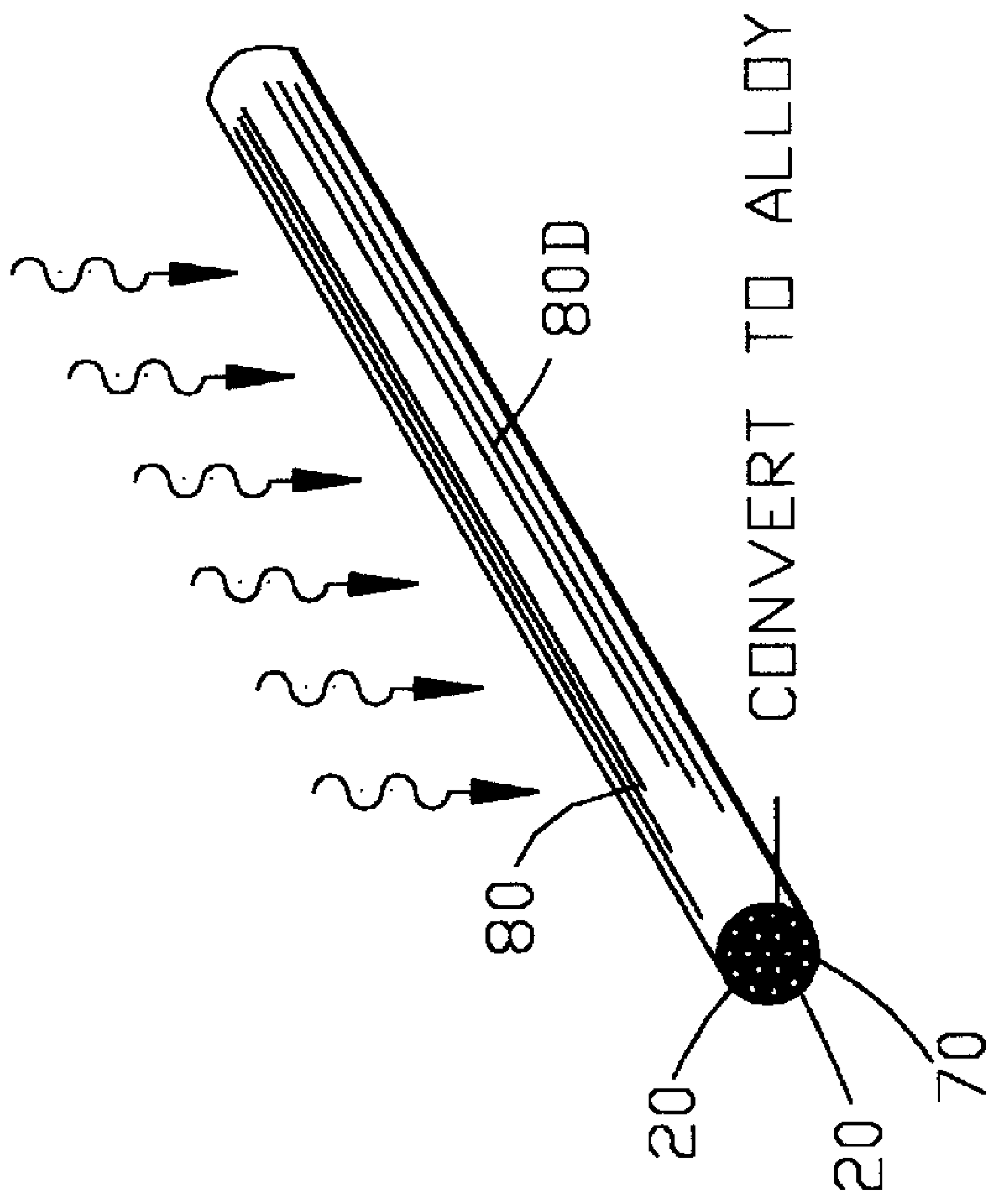


FIG. 7

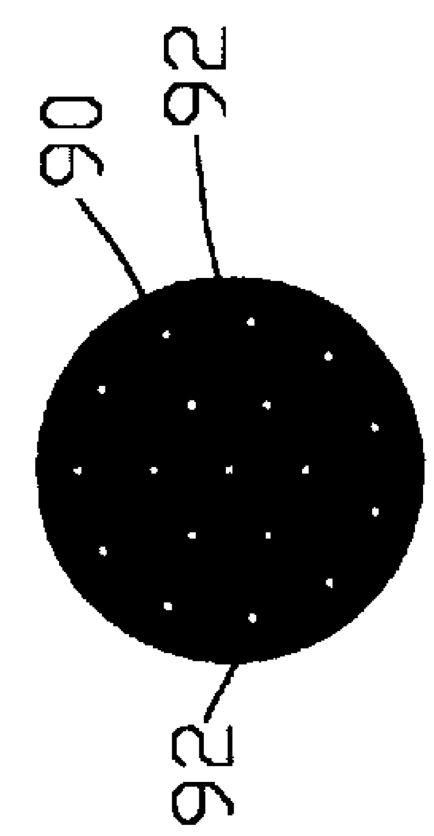


FIG. 7A

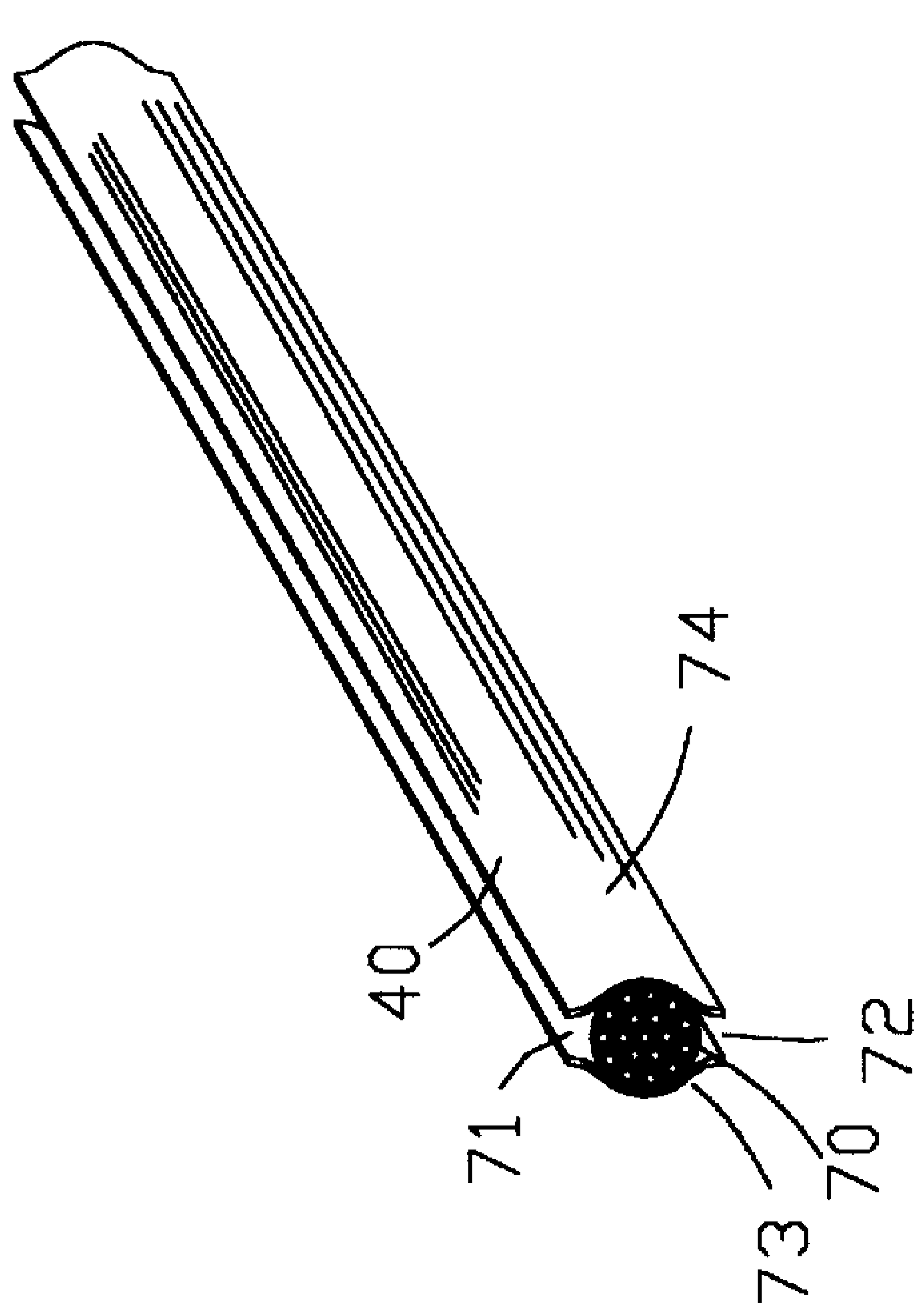


FIG. 6

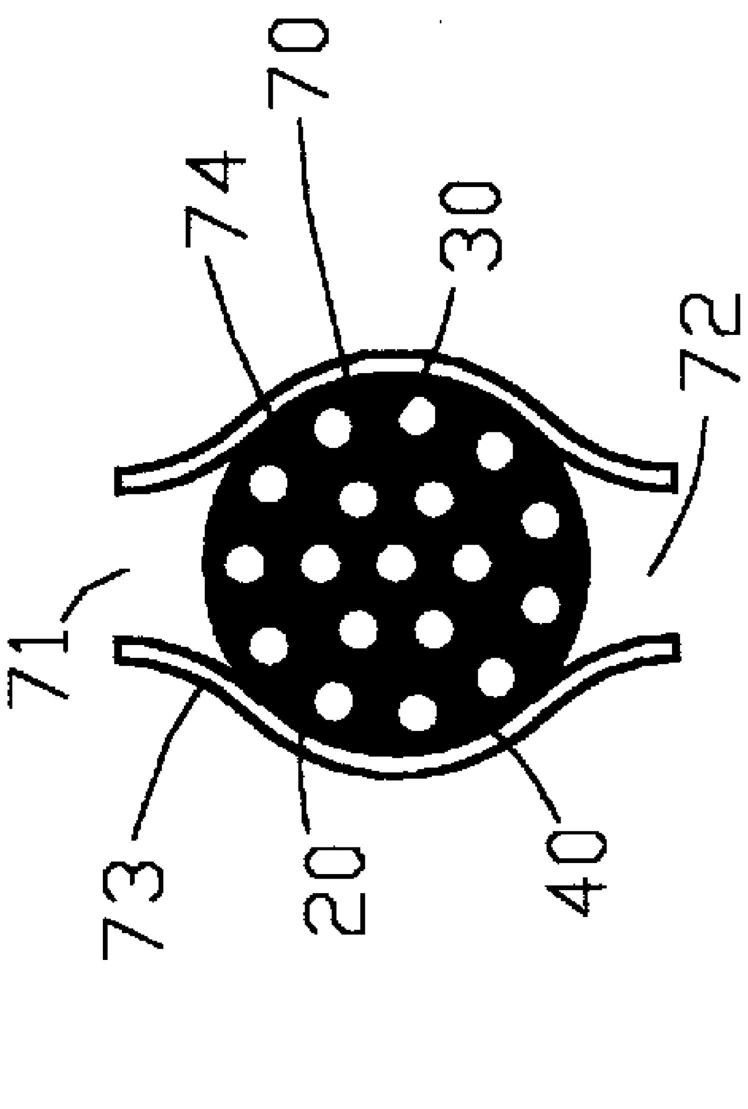


FIG. 6A

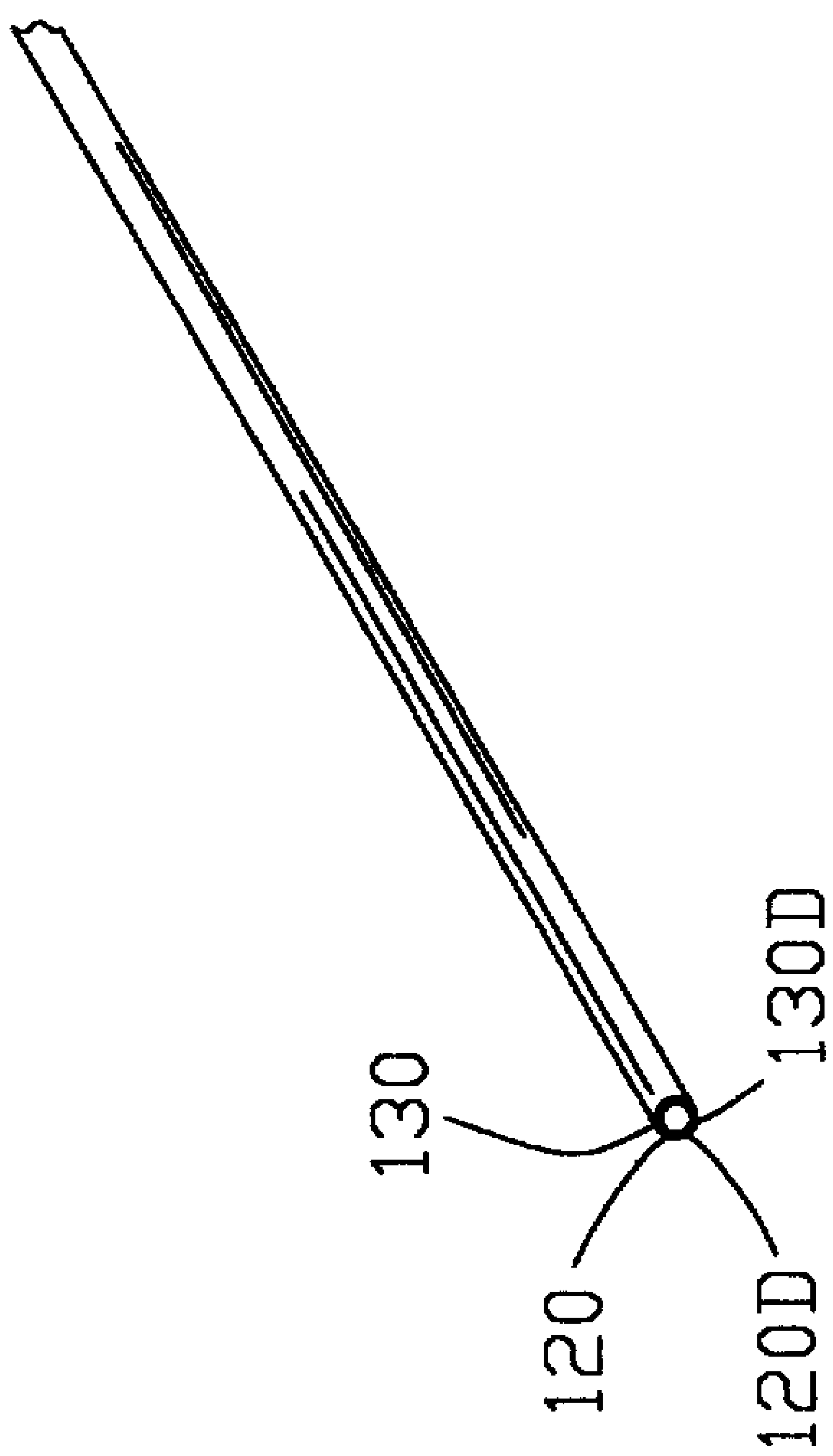


FIG. 9

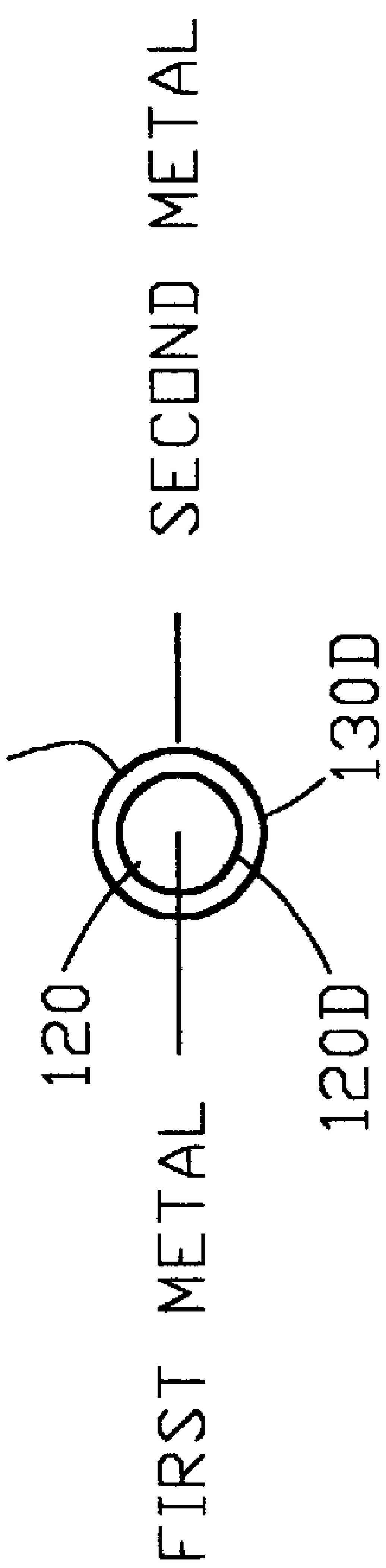


FIG. 9A

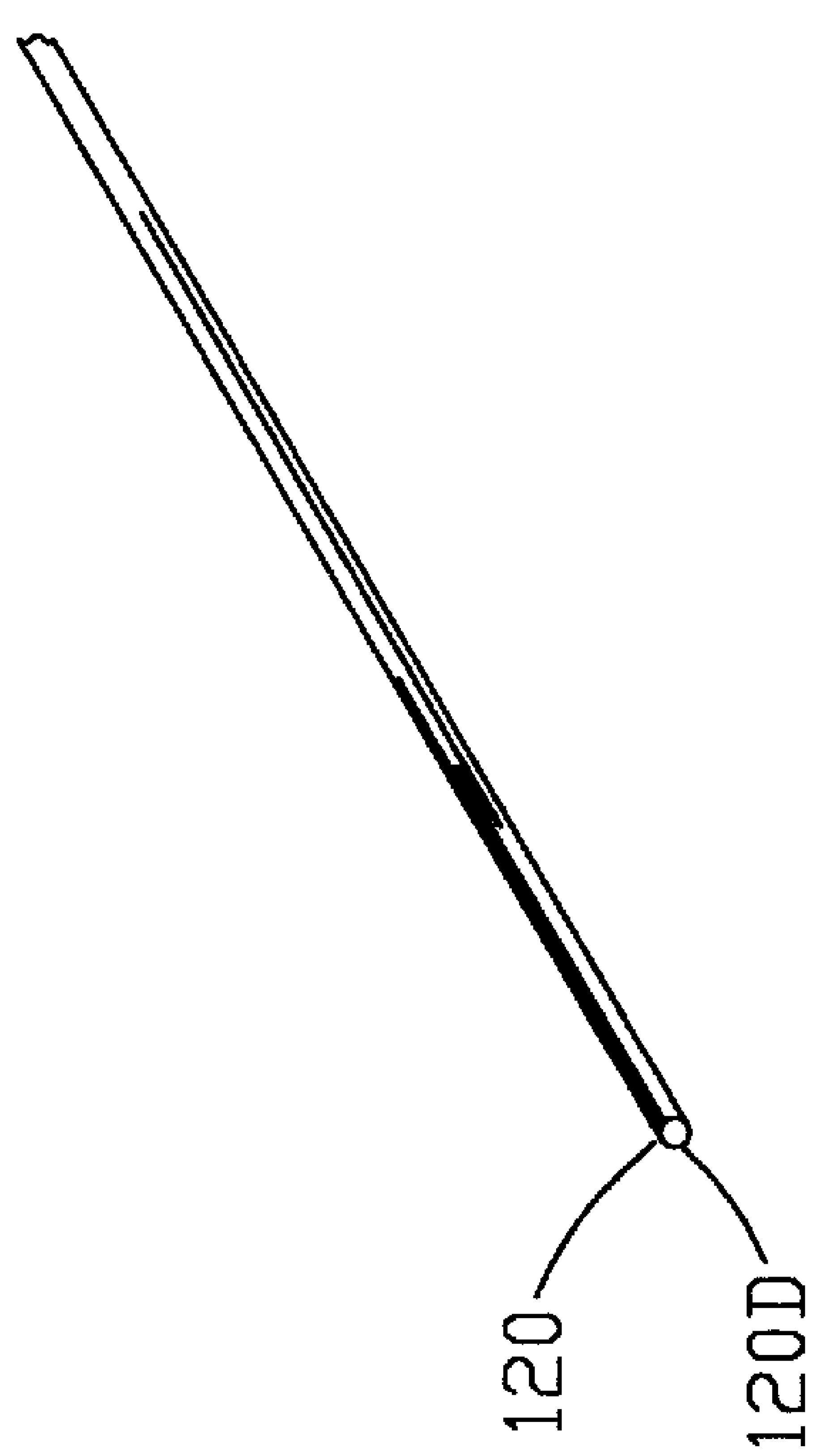


FIG. 8

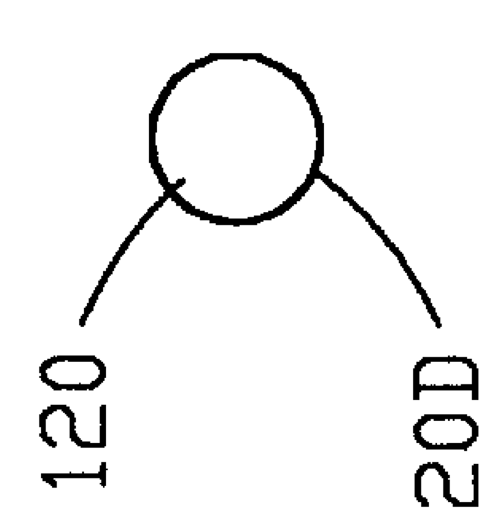


FIG. 8A

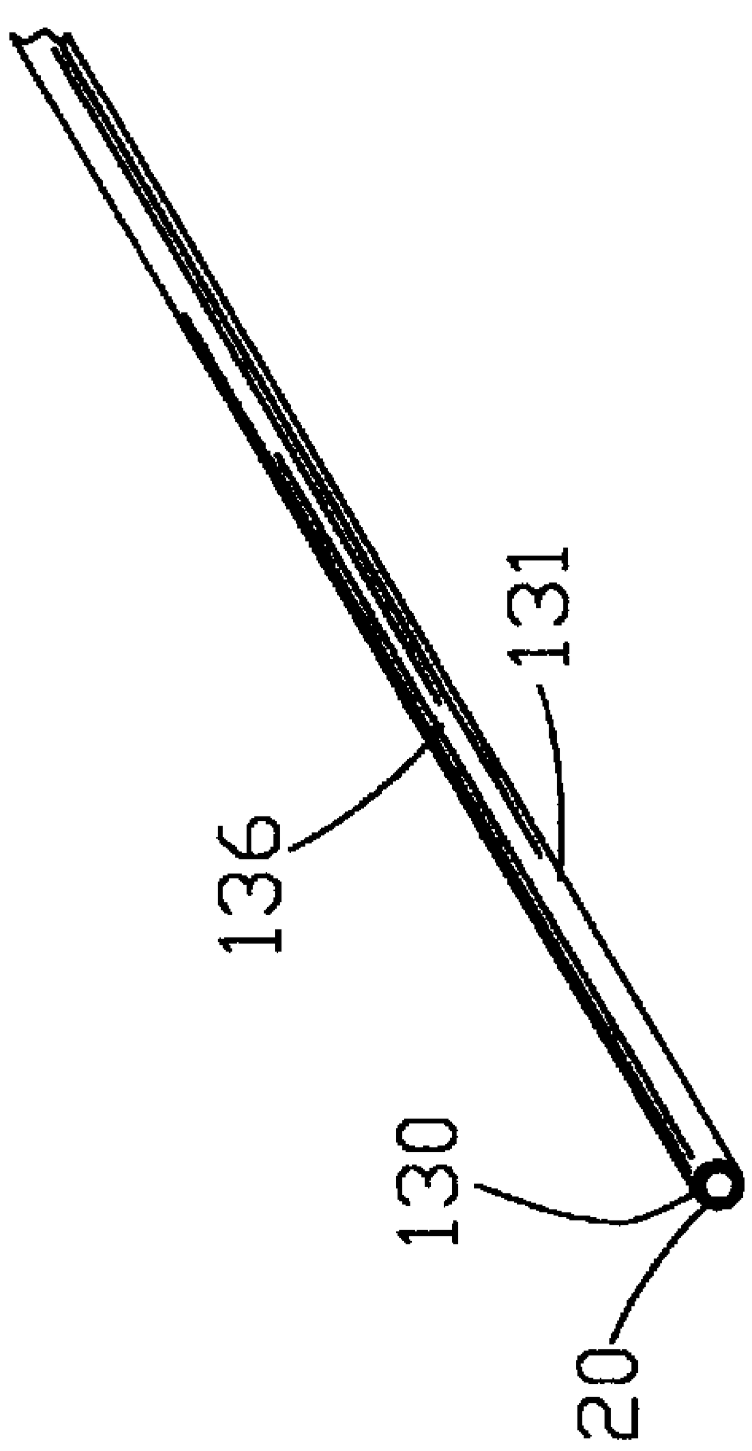


FIG. 10

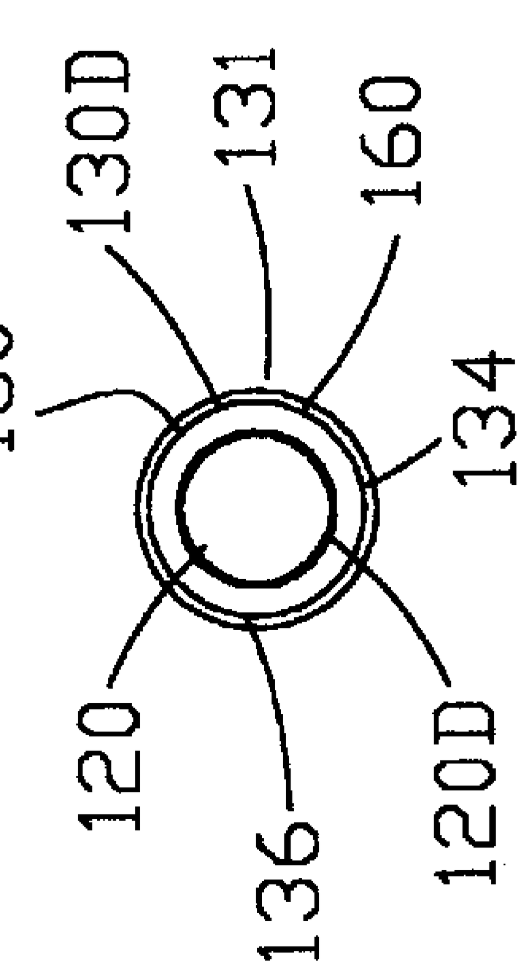


FIG. 10A

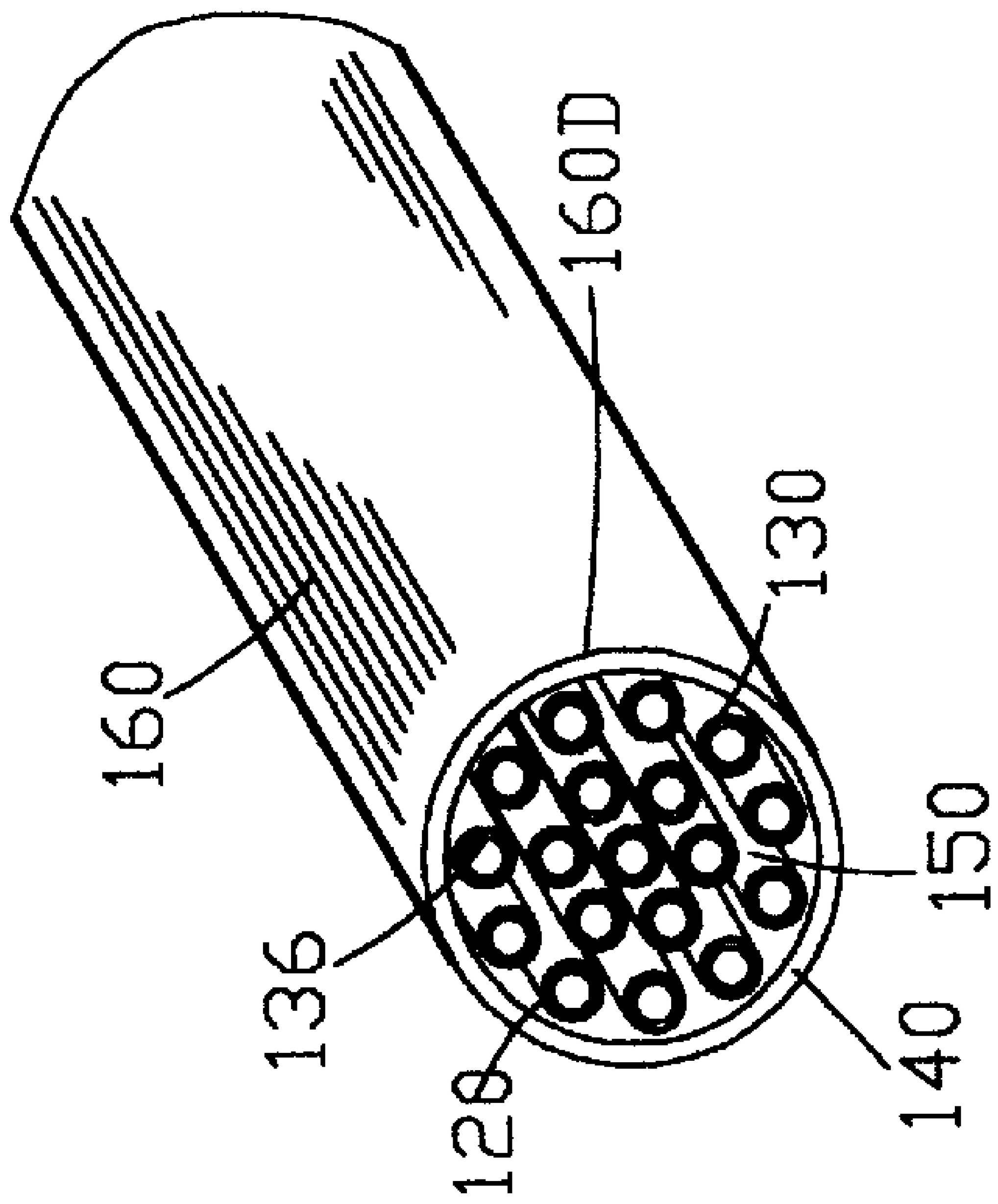


FIG. 11

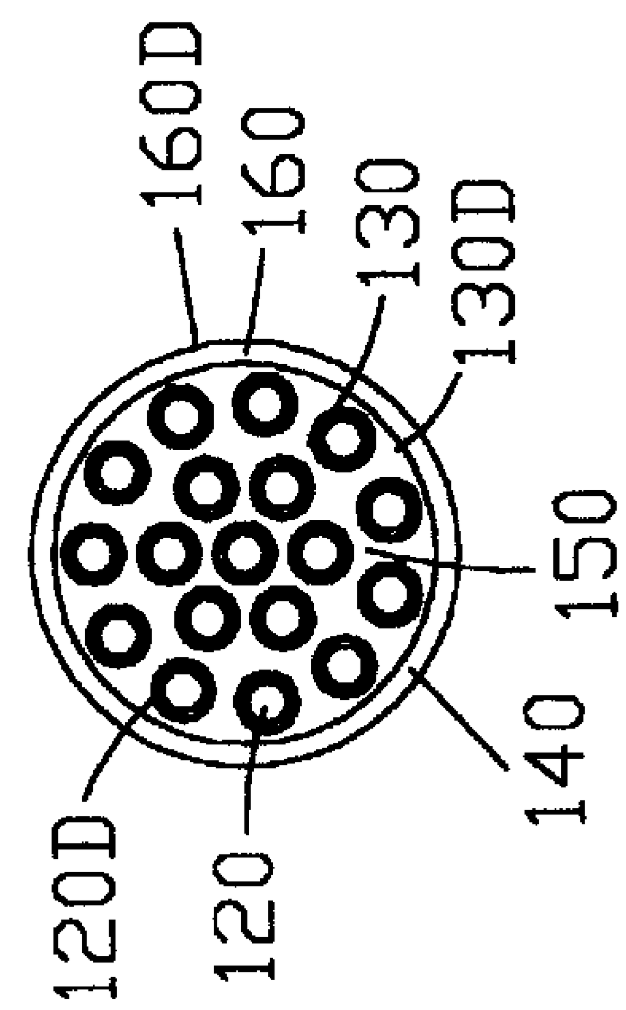


FIG. 11A

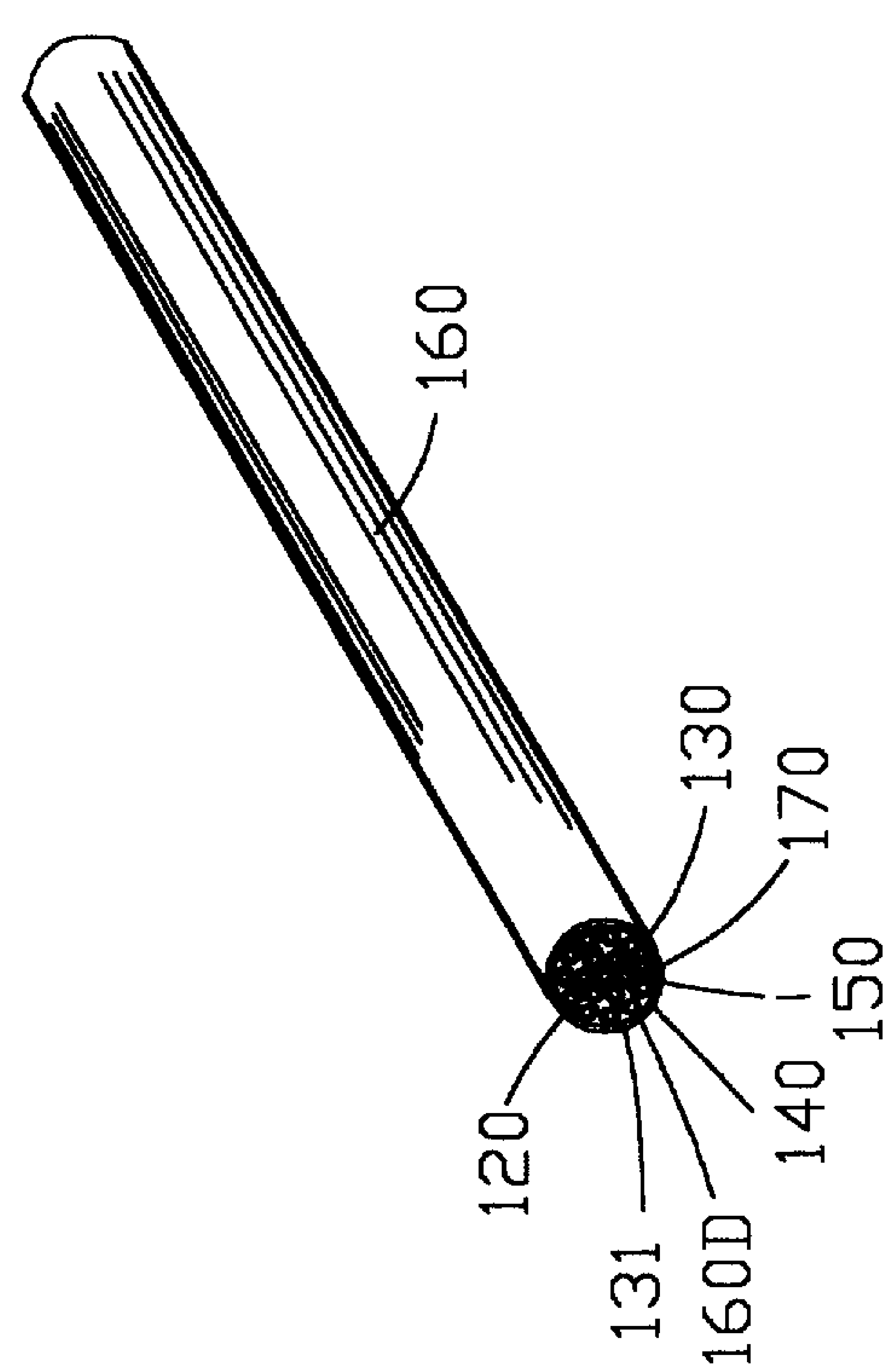


FIG. 12

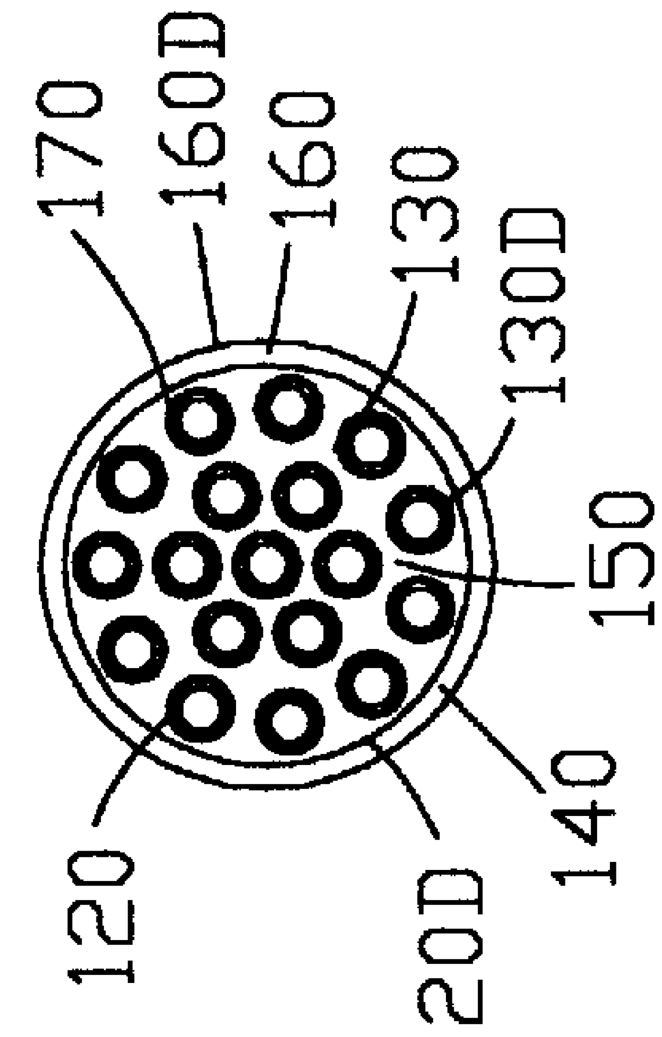


FIG. 12A

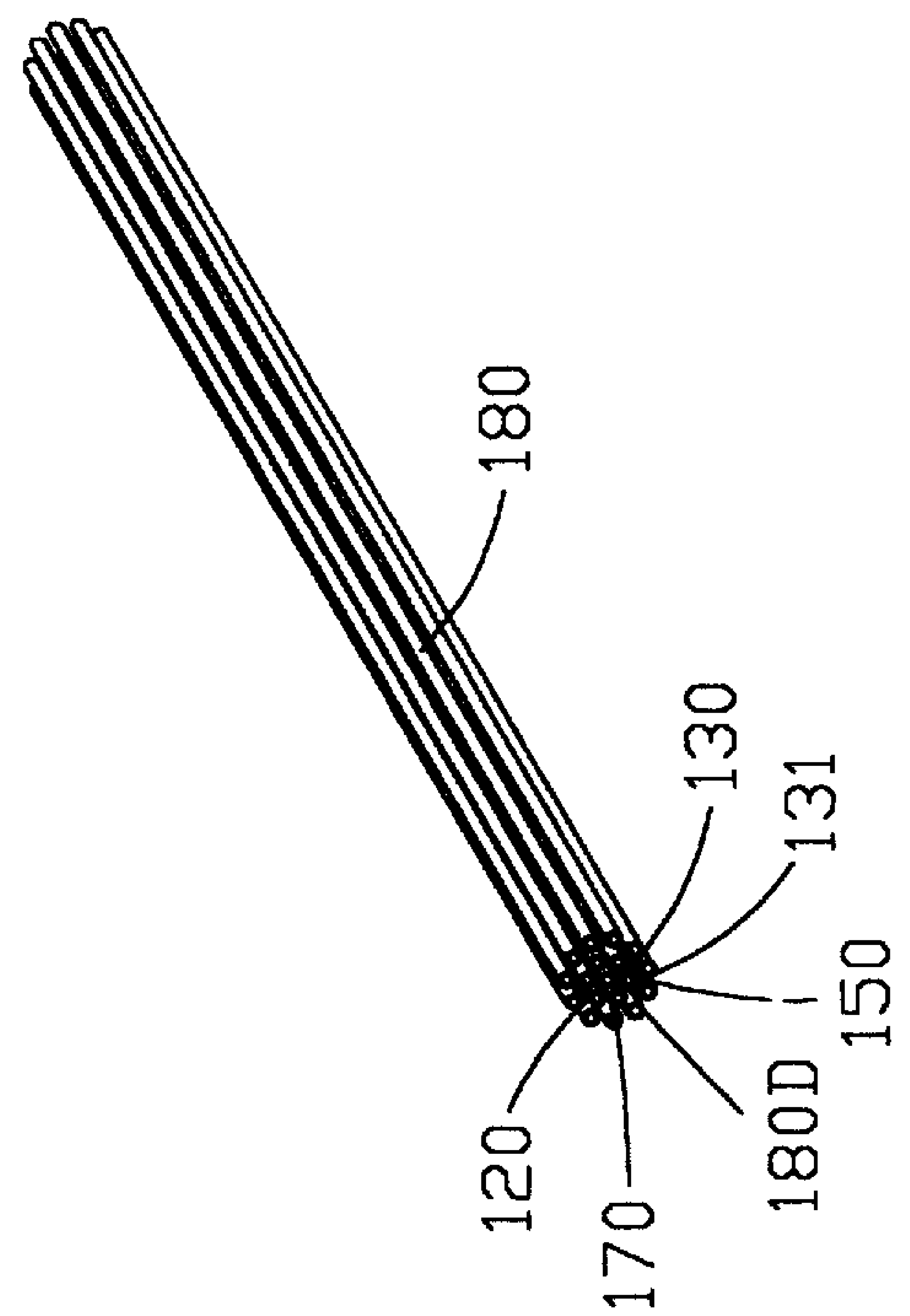


FIG. 13

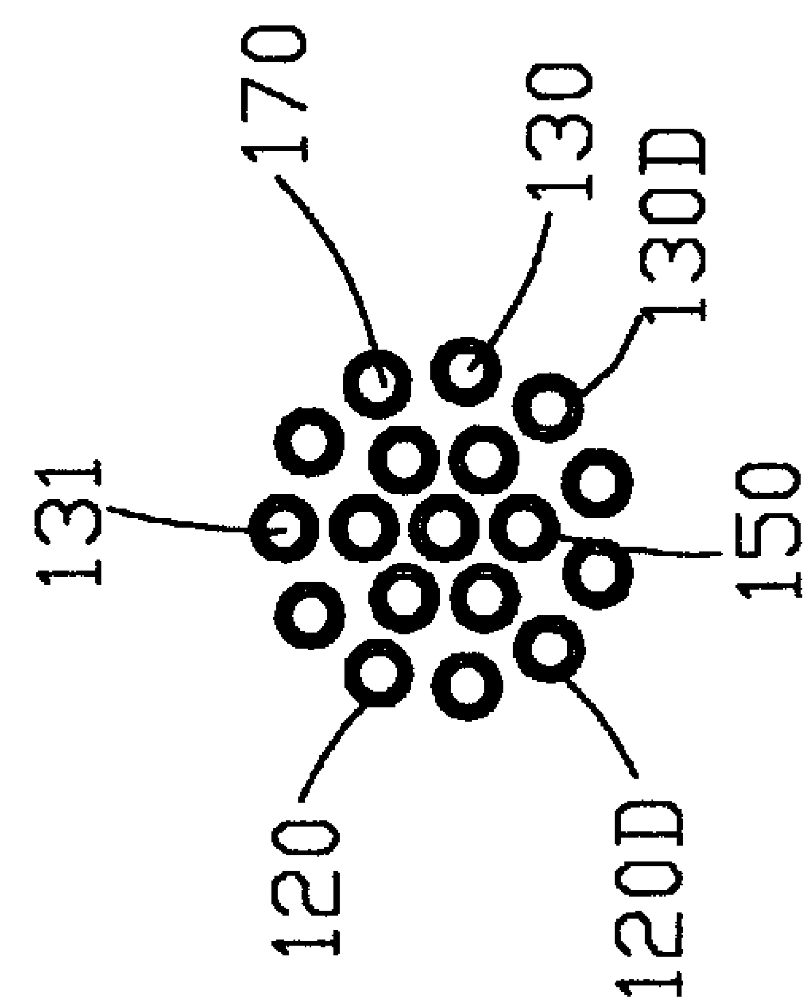


FIG. 13A

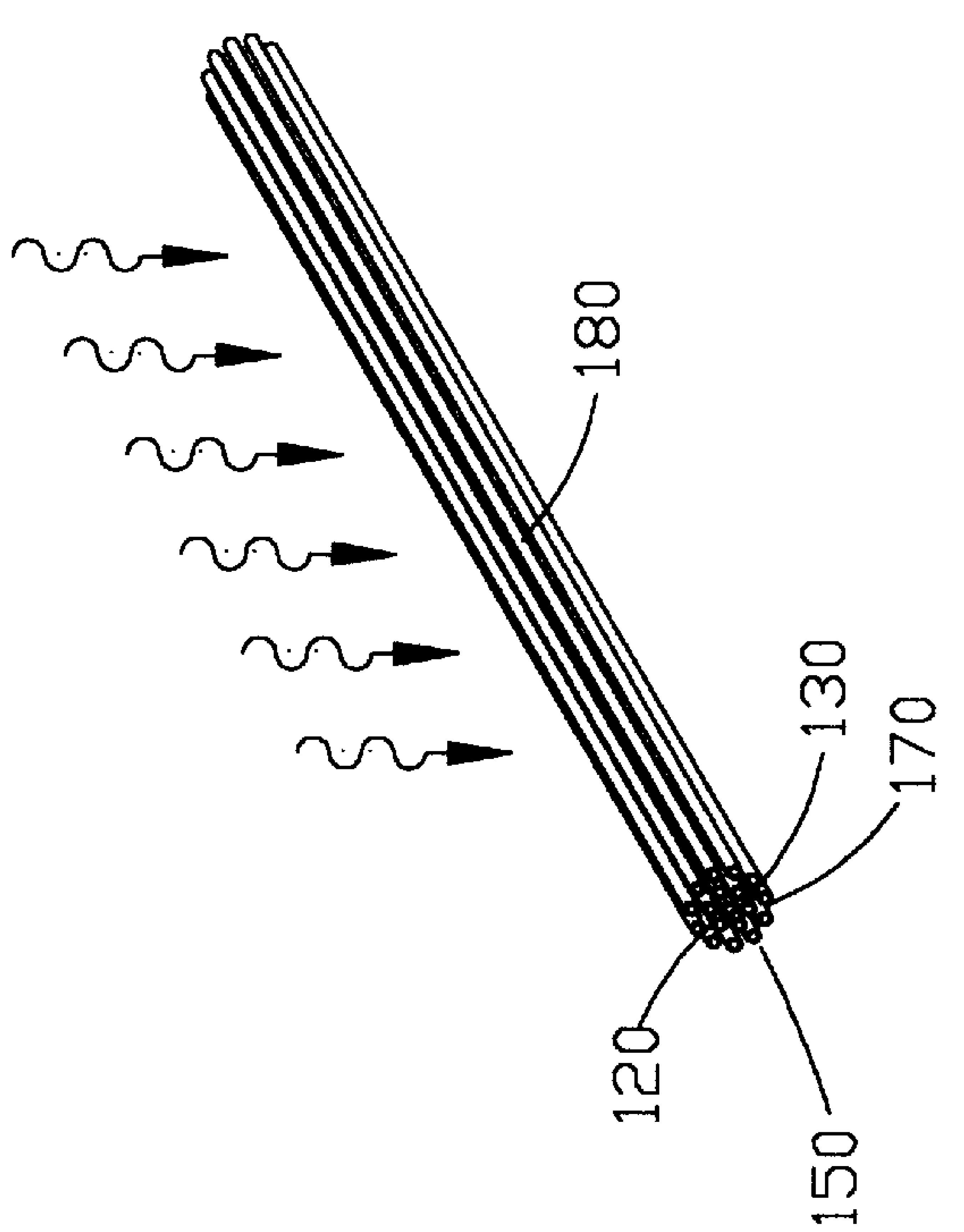


FIG. 14

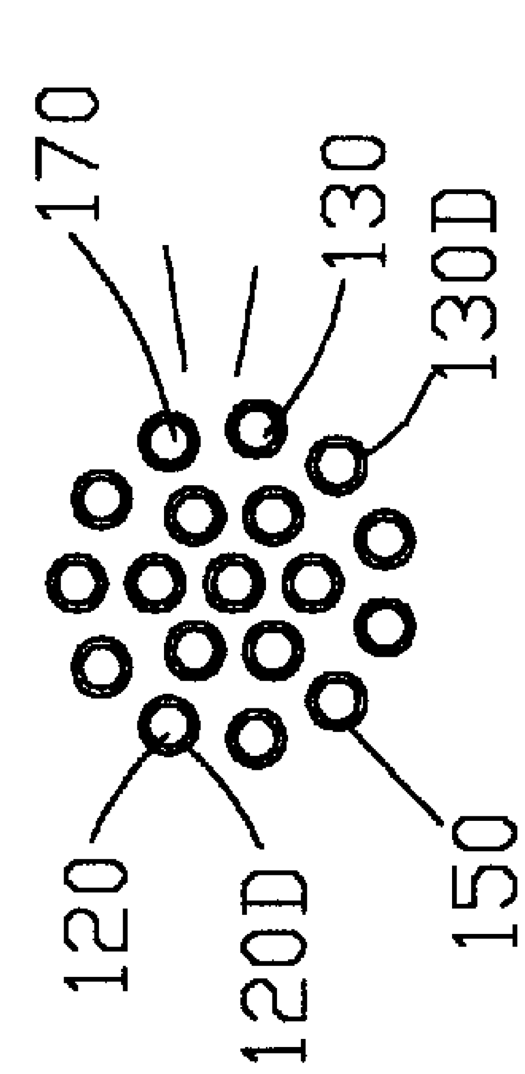


FIG. 14A

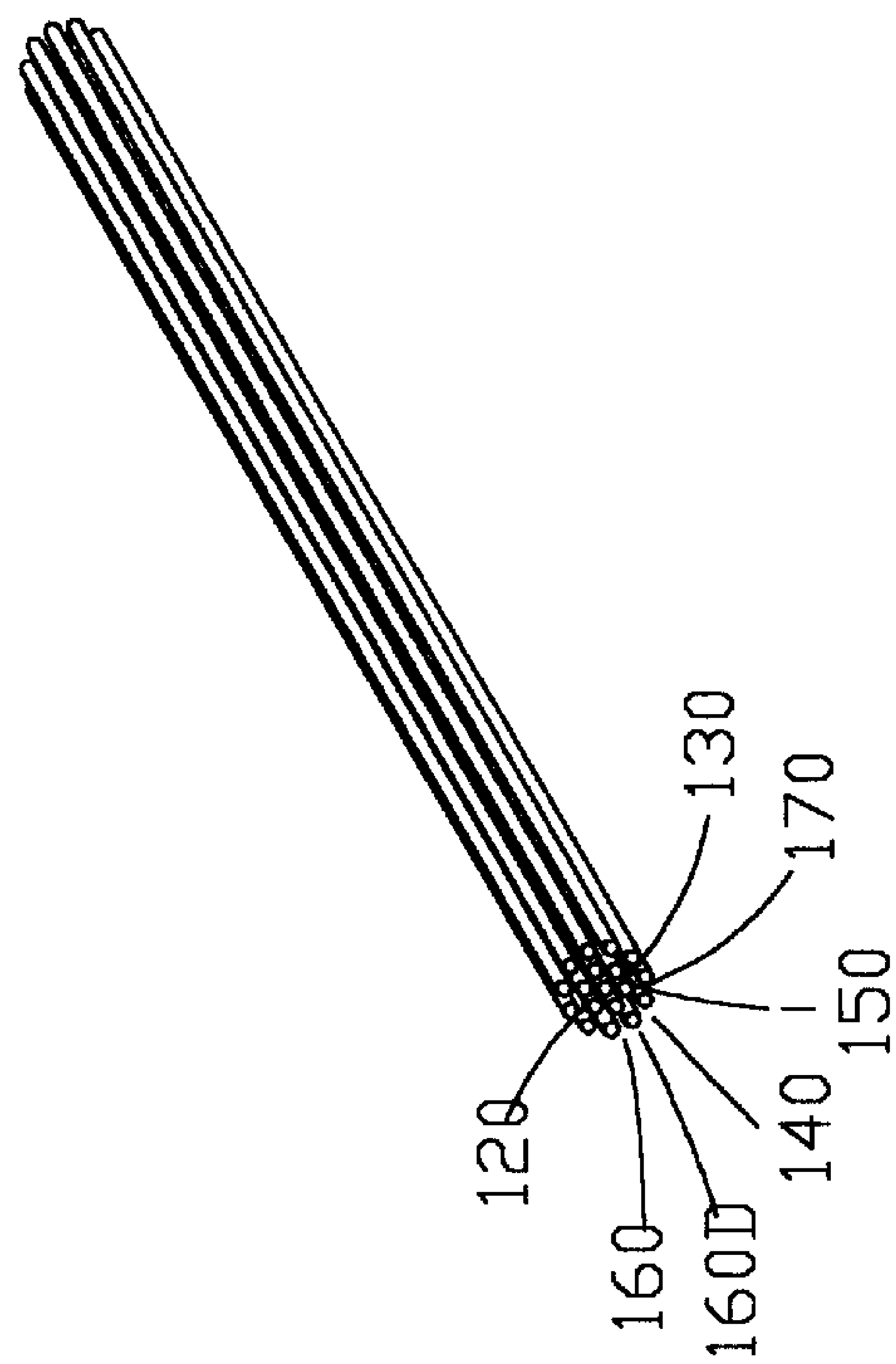
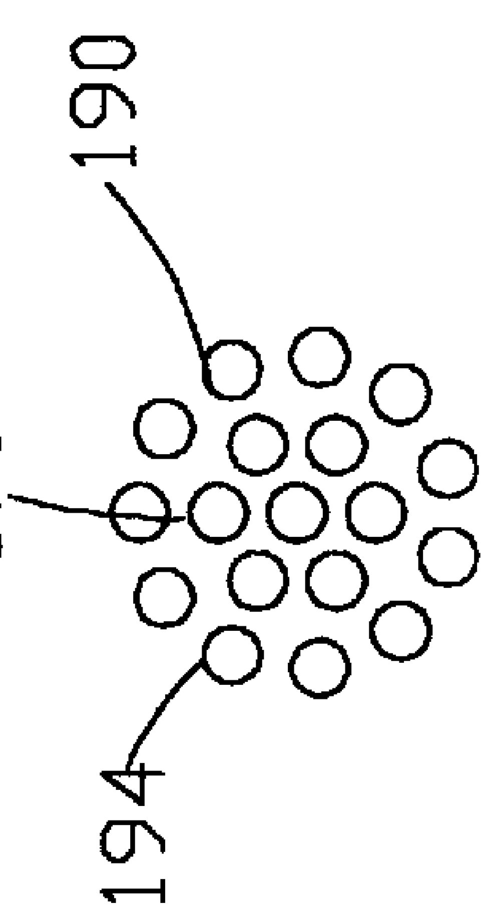


FIG. 15



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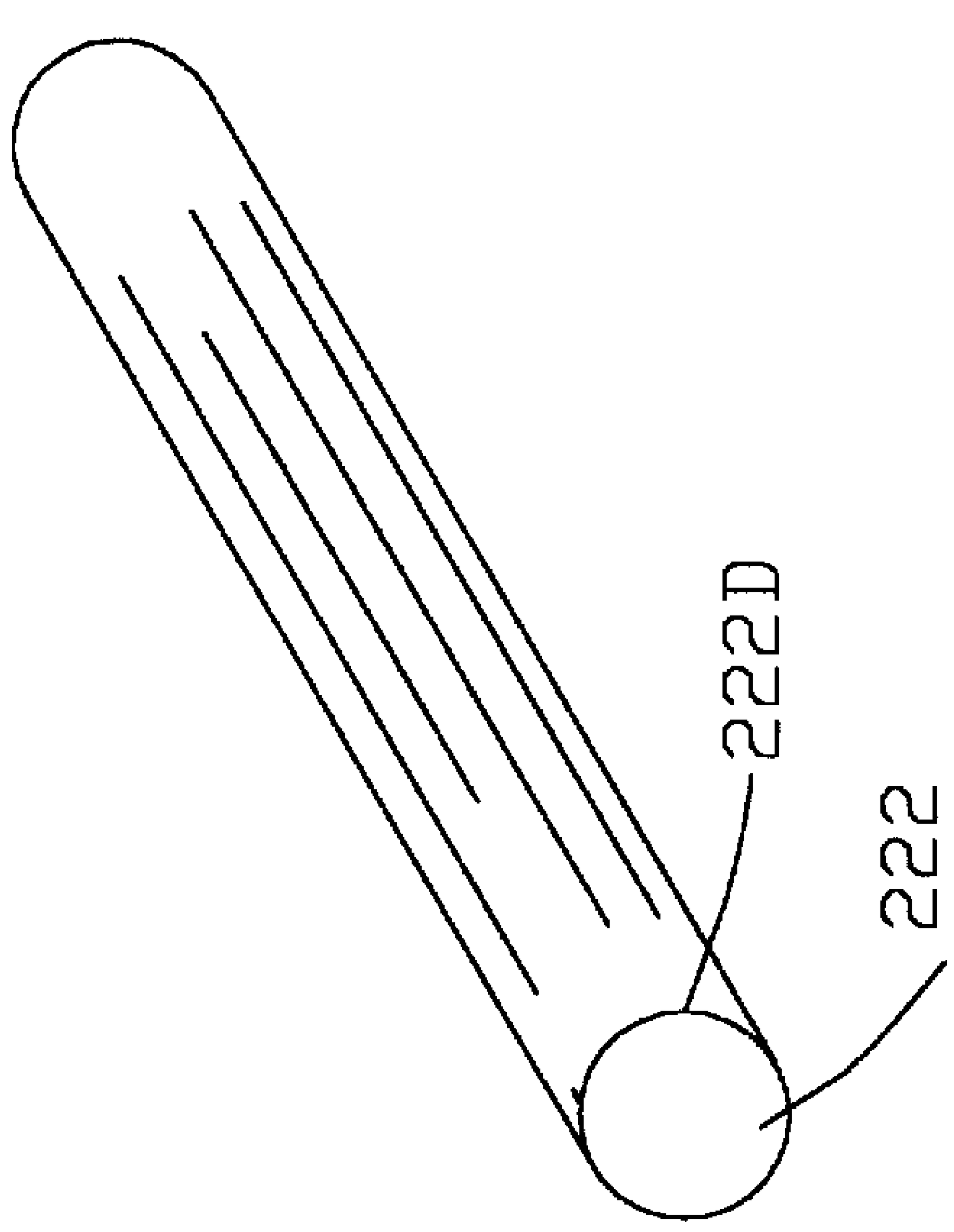

FIG. 16

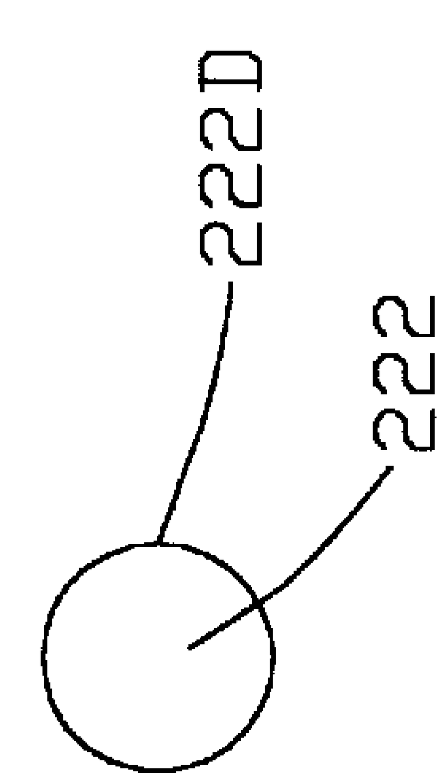

FIG. 16A

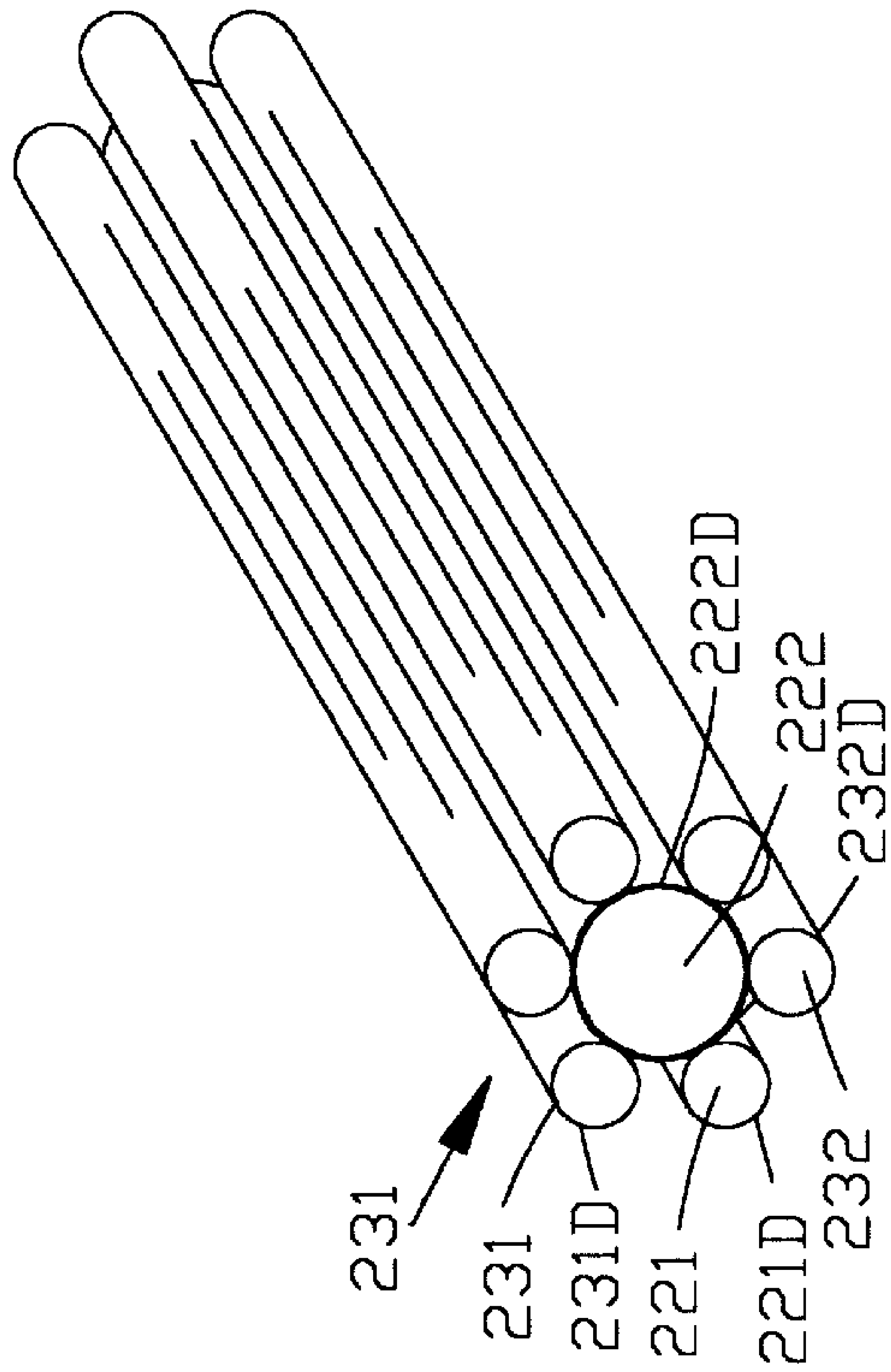

FIG. 17

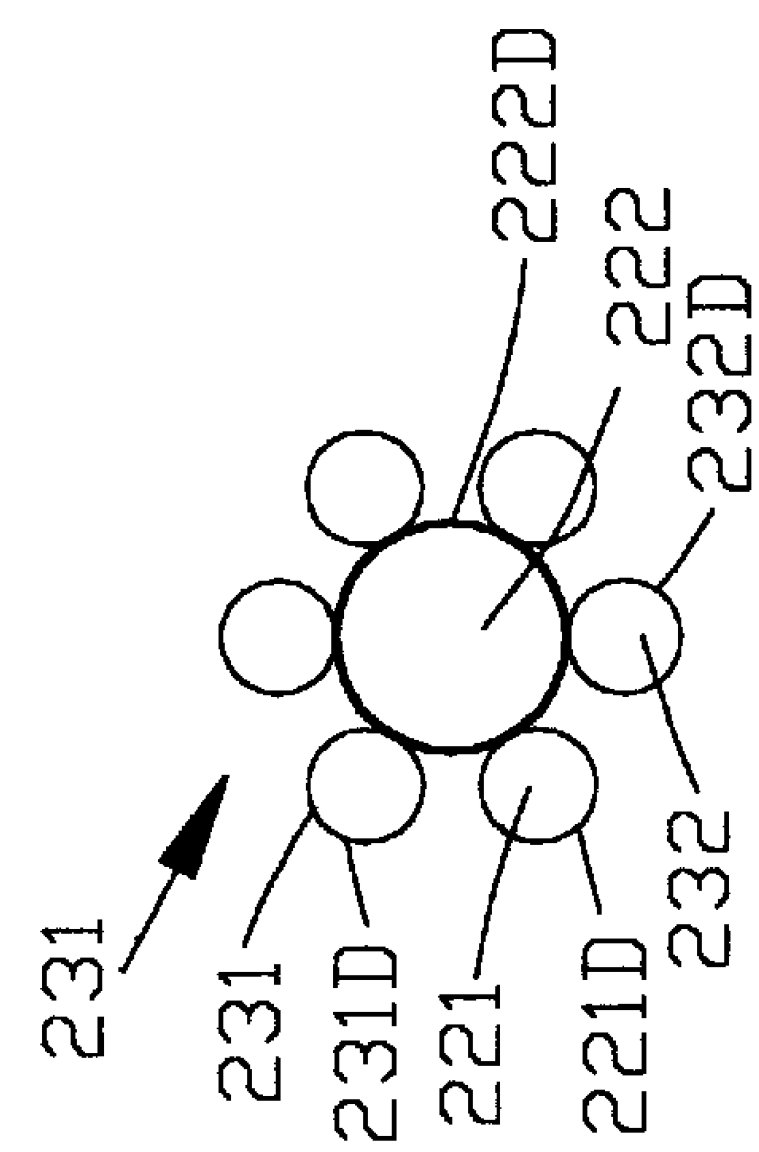

FIG. 17A

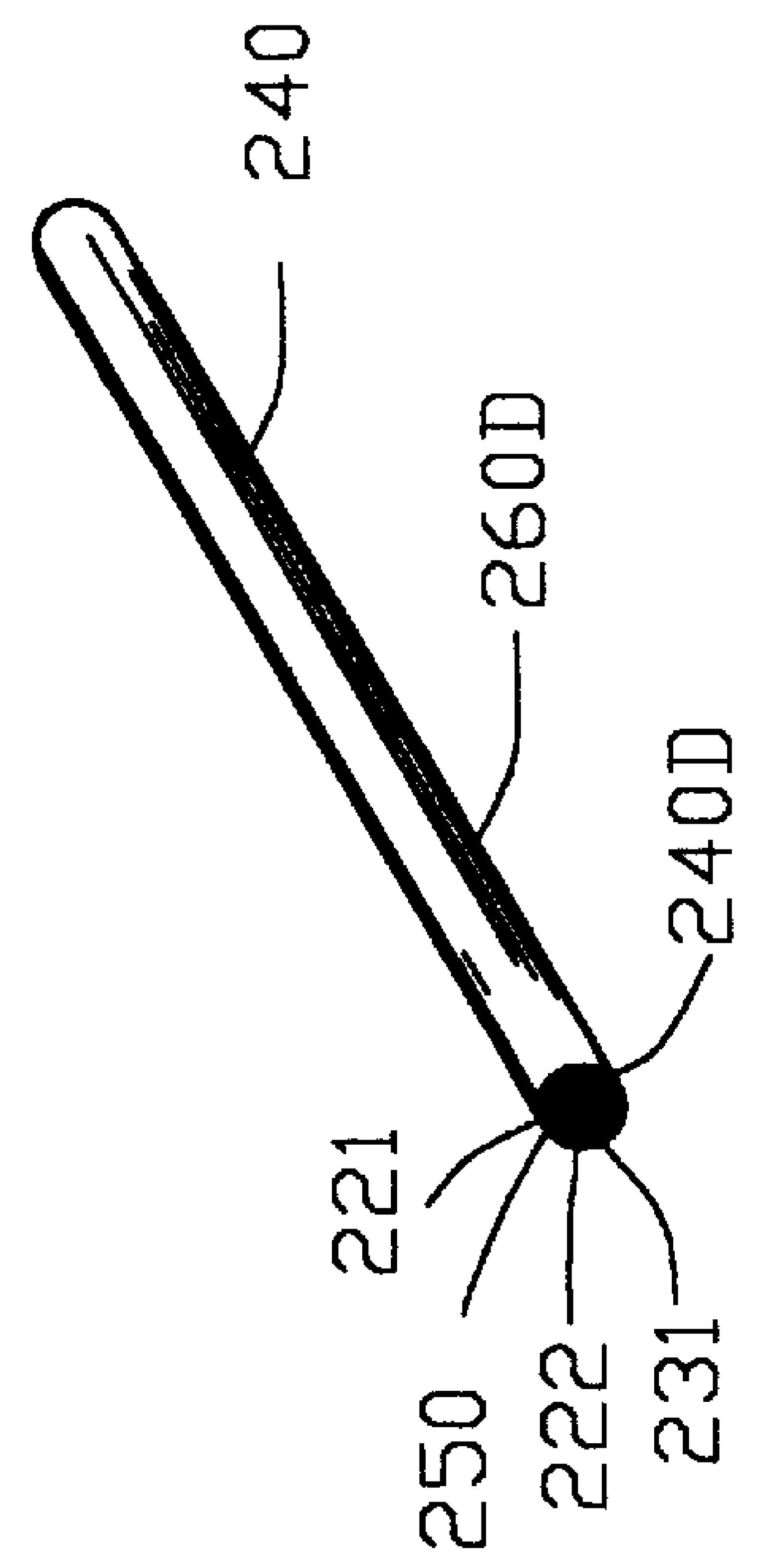

FIG. 19

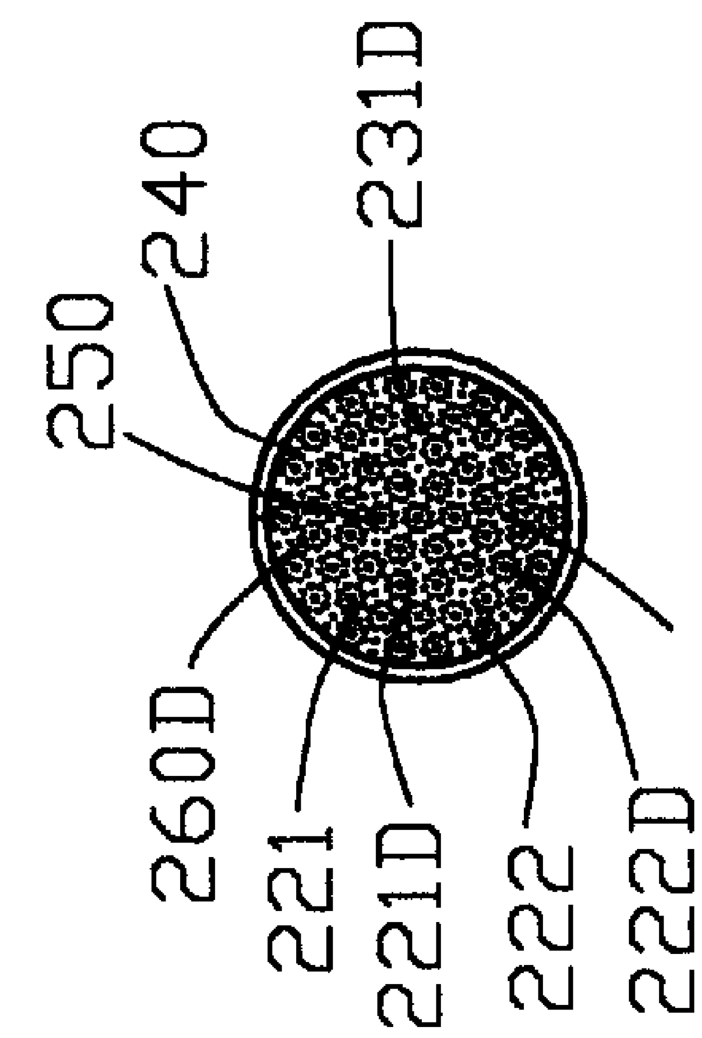

FIG. 19A

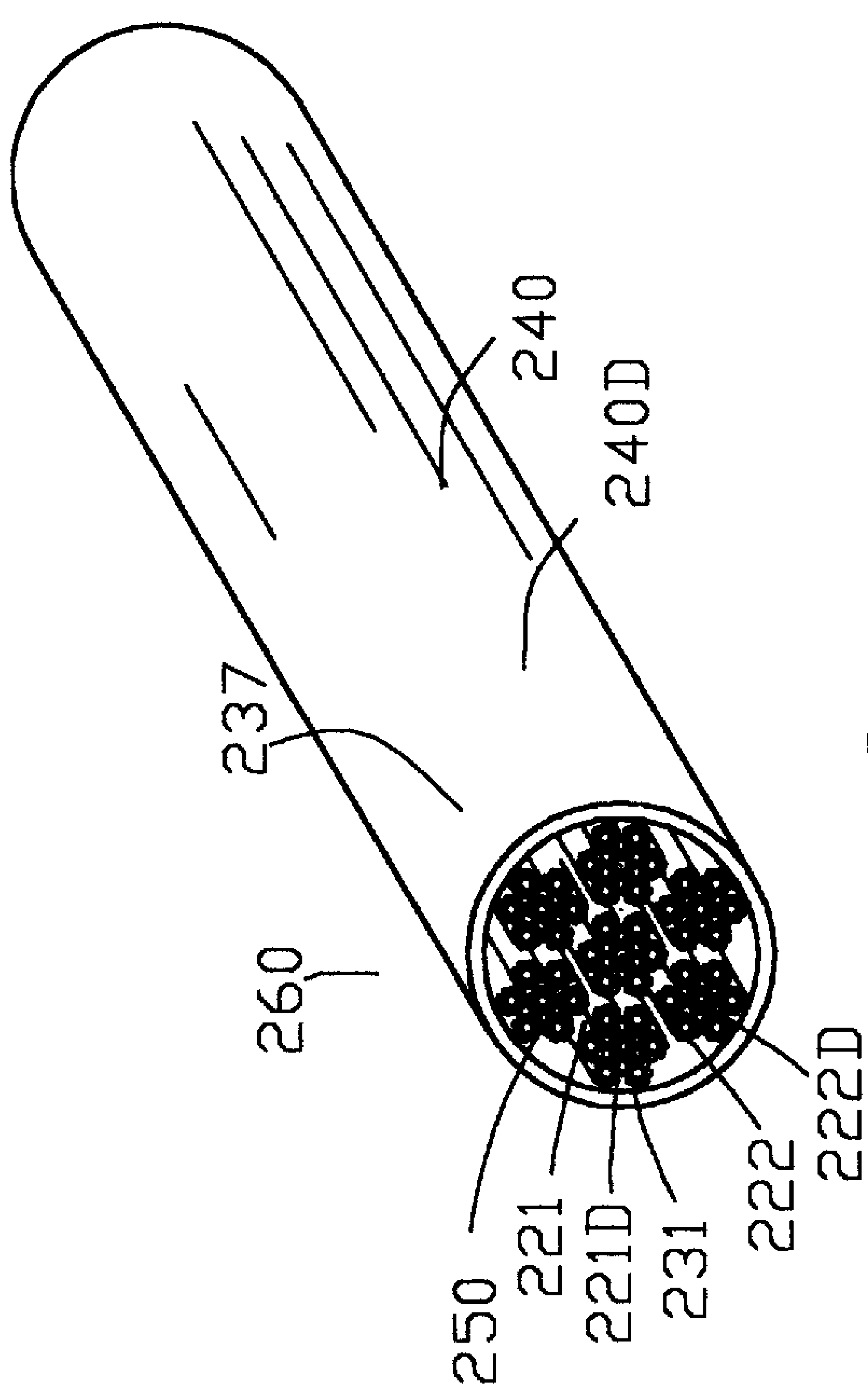

FIG. 18

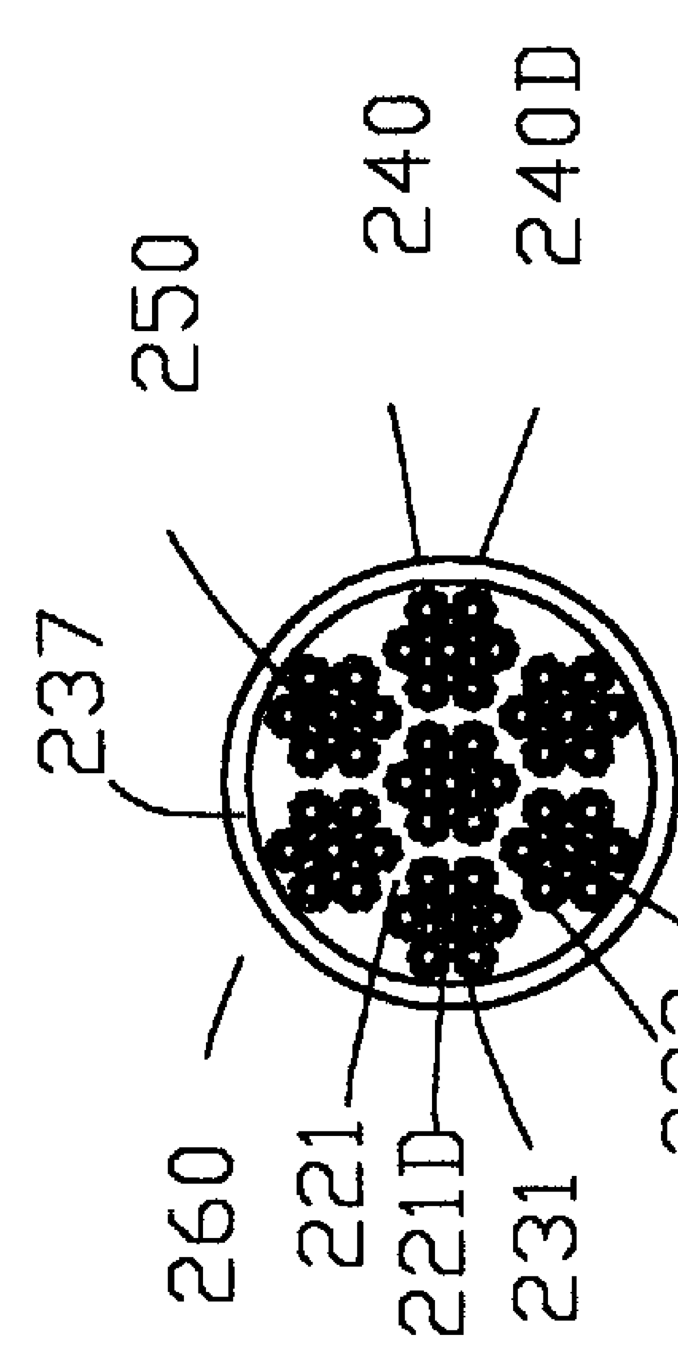

FIG. 18A

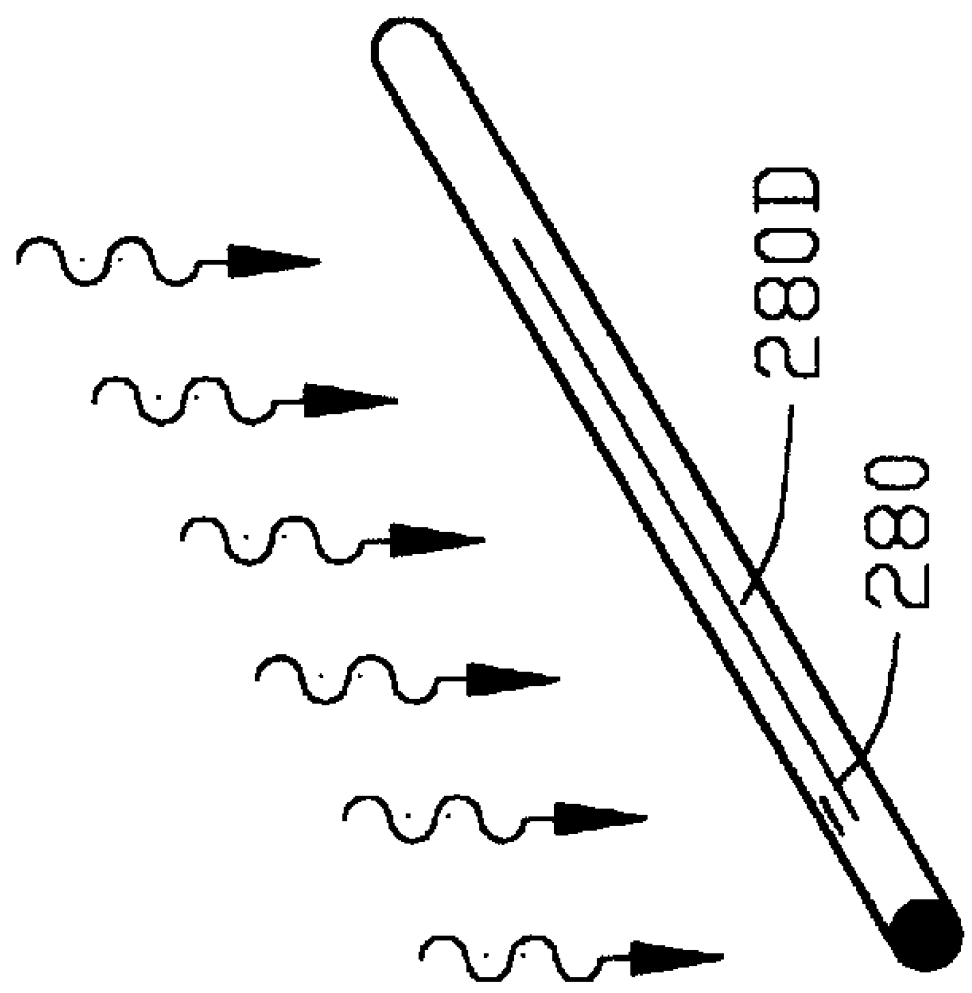

FIG. 21

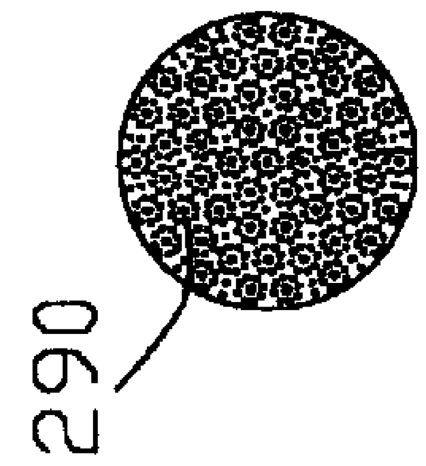

FIG. 21A

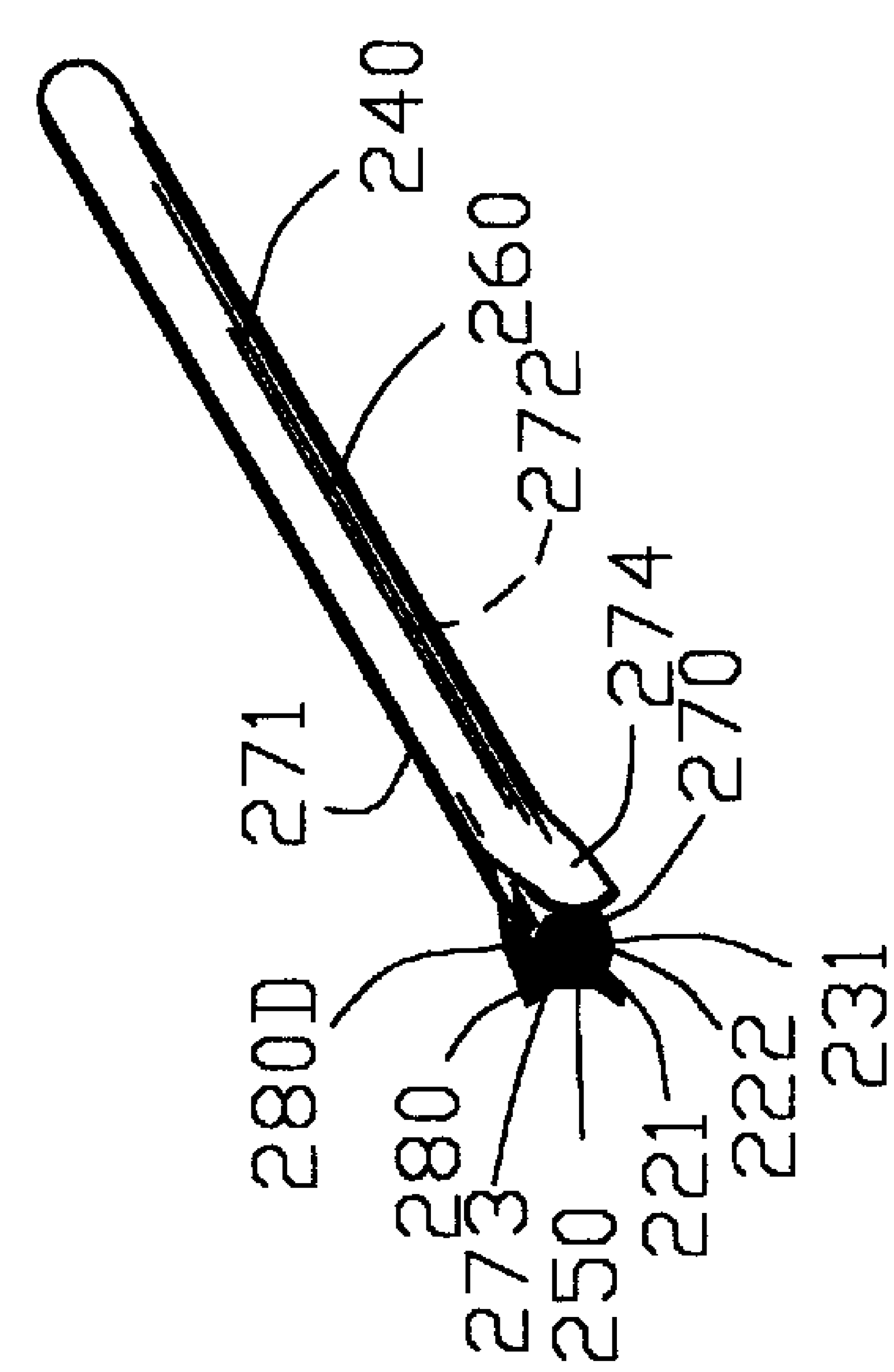

FIG. 20

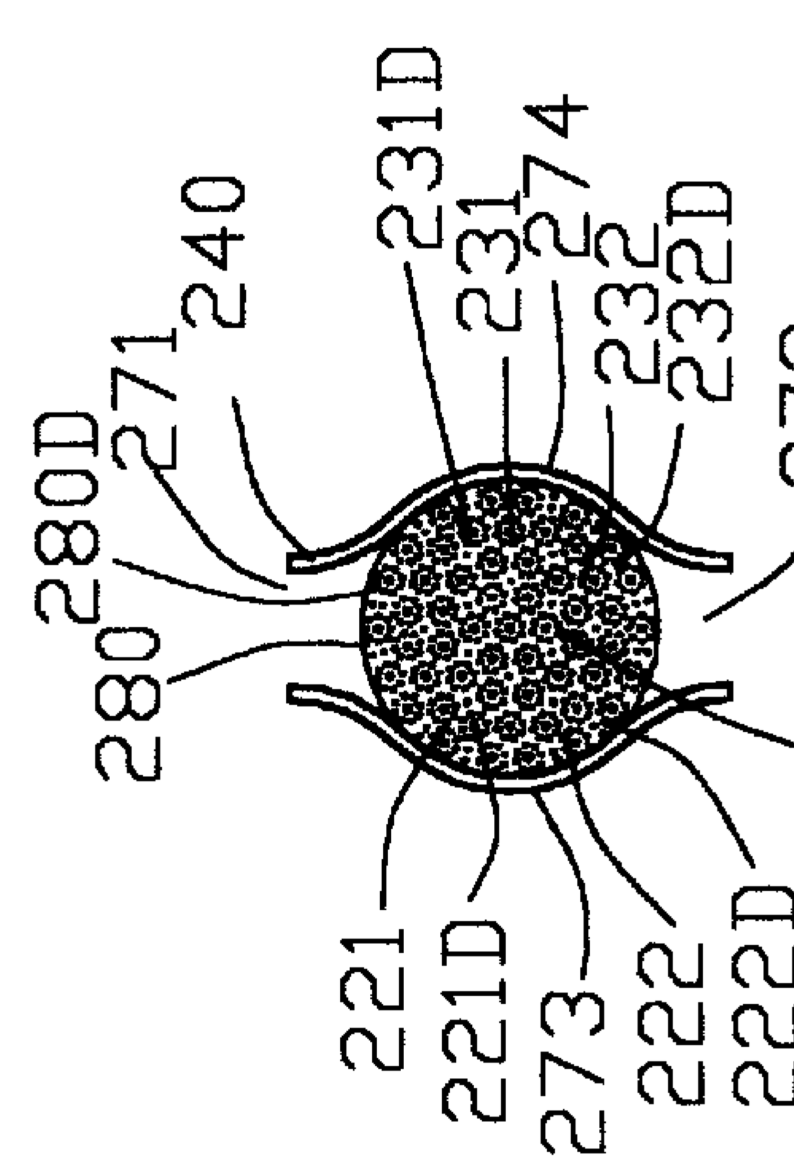

FIG. 20A

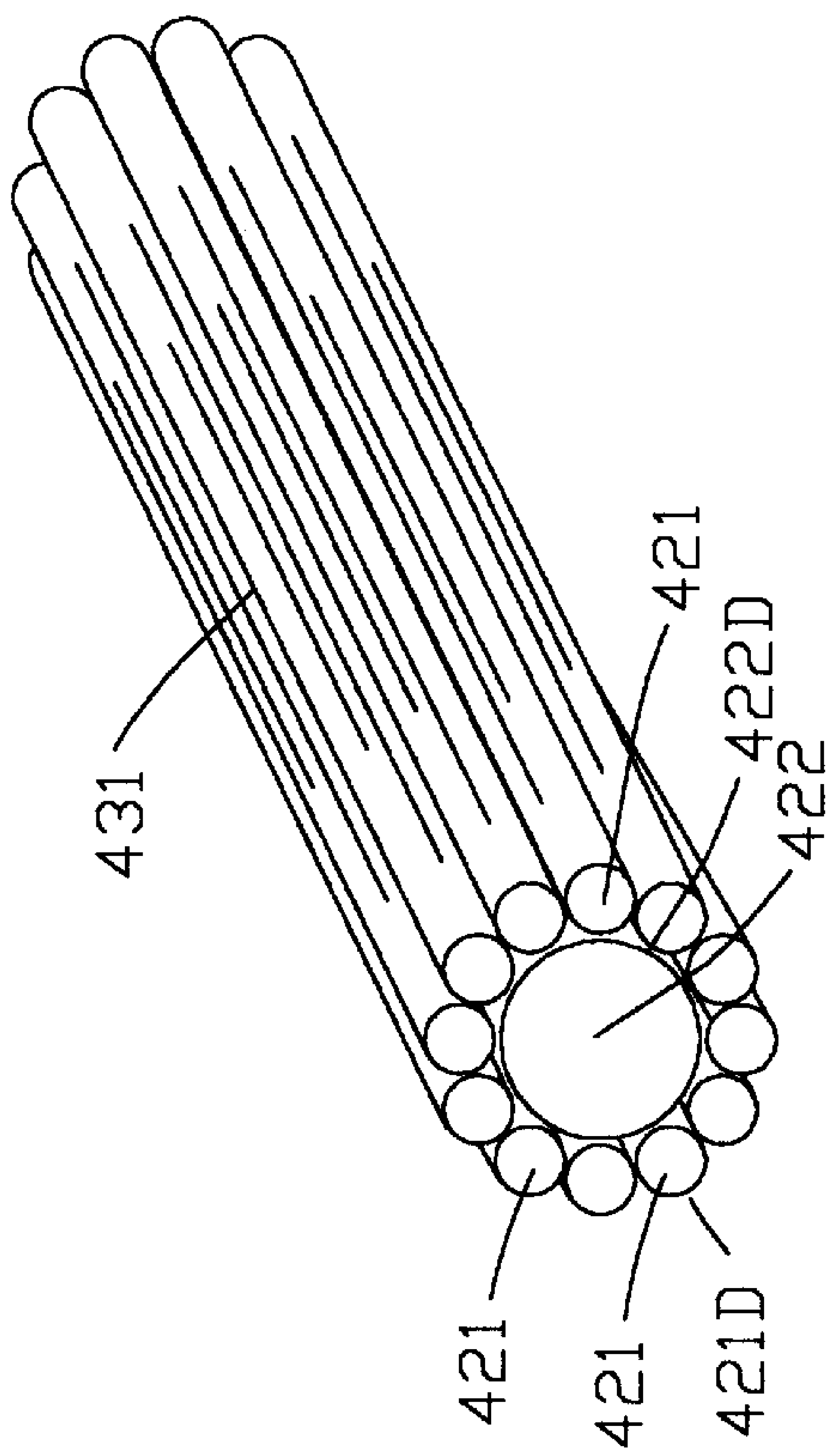

FIG. 23

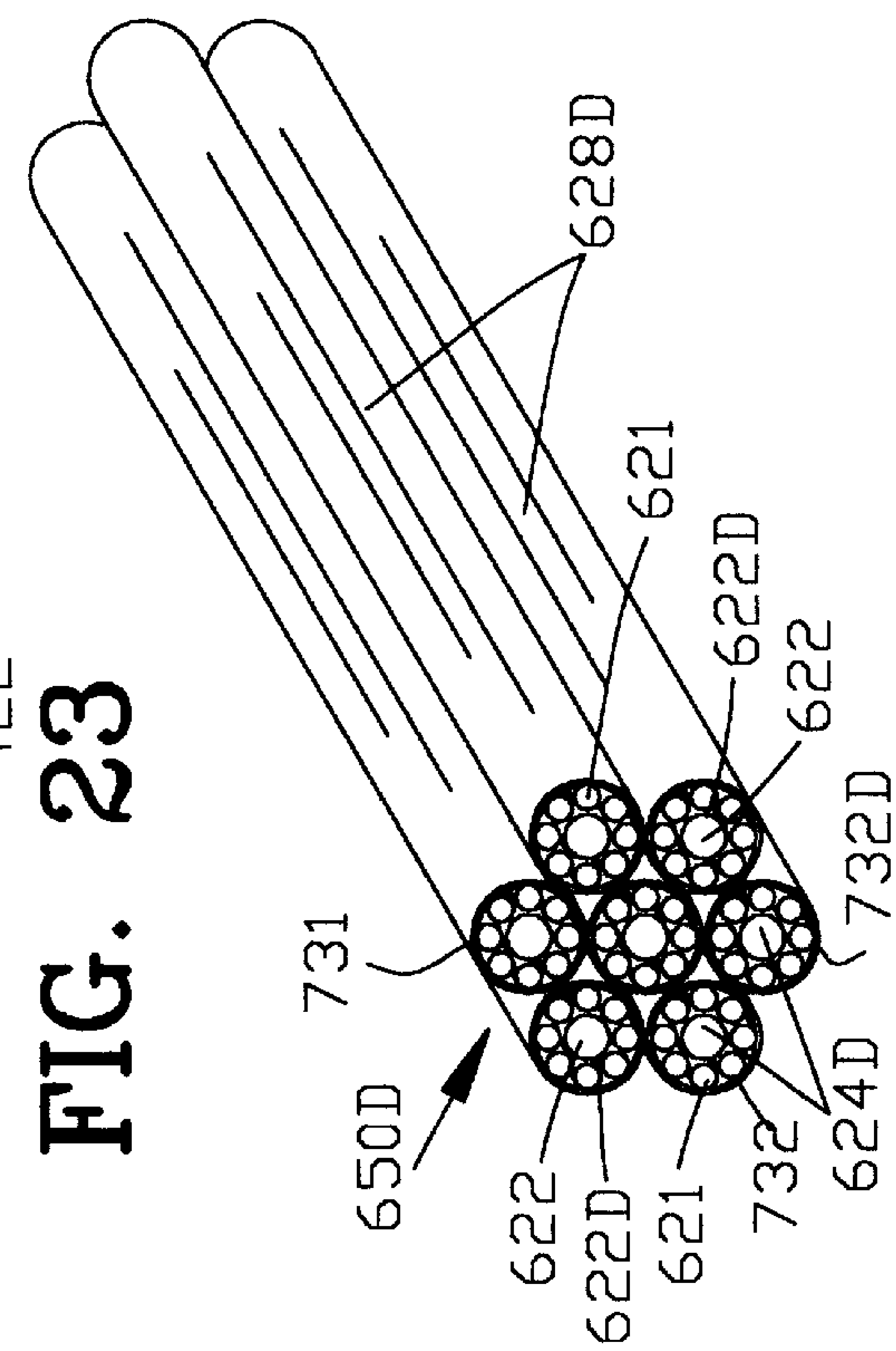

FIG. 25

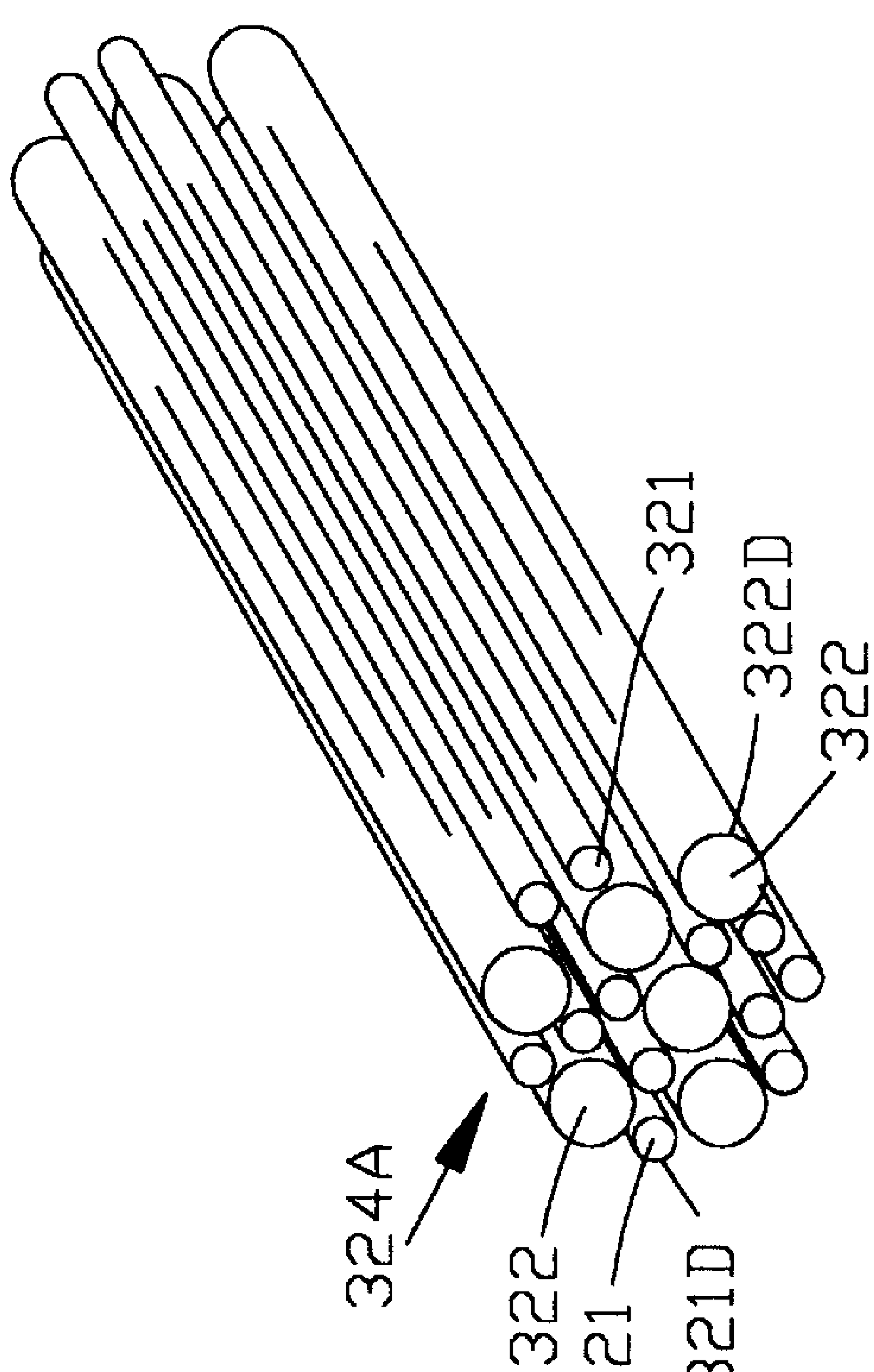

FIG. 22

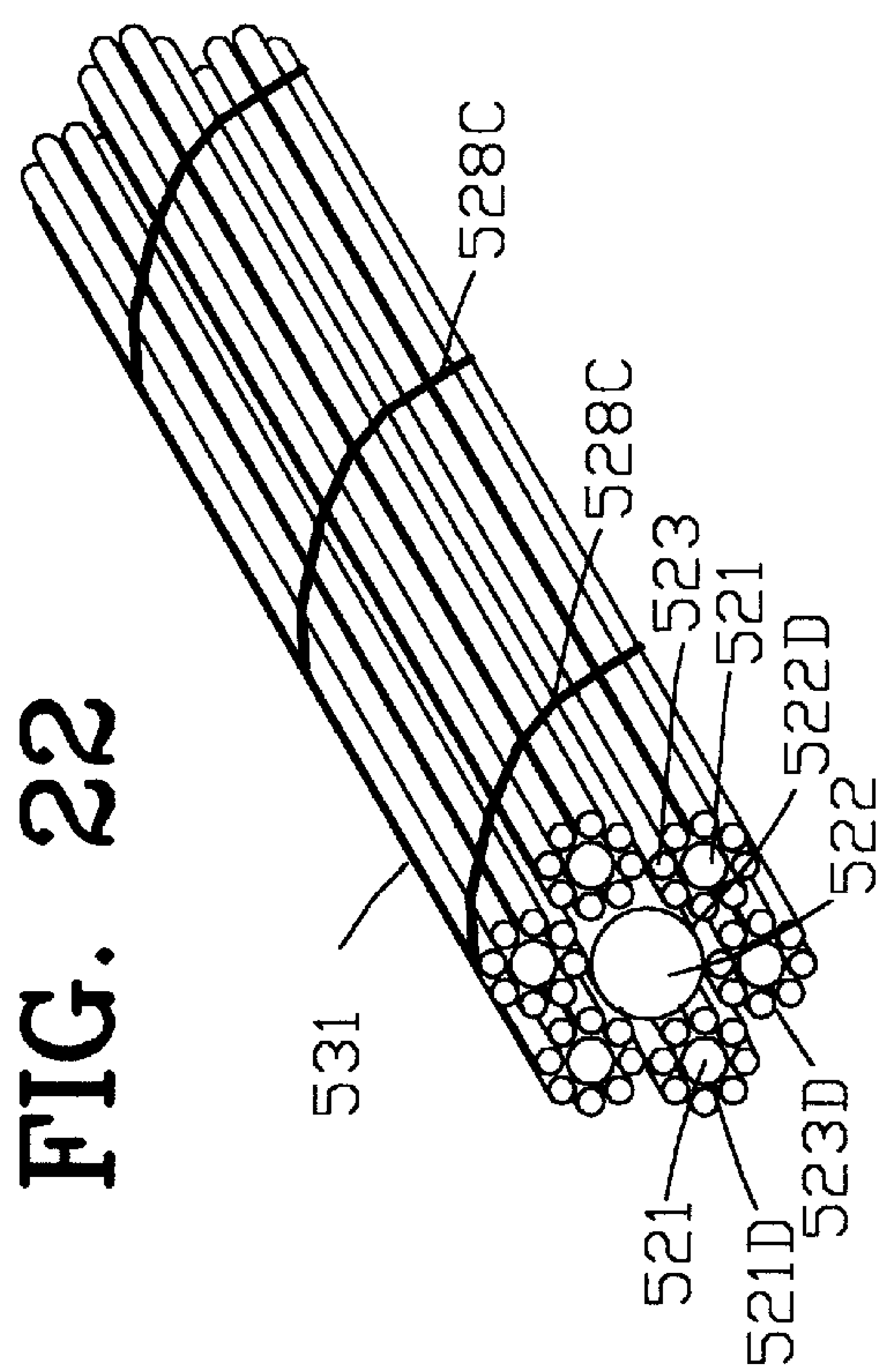

FIG. 24

PROCESS FOR MAKING AN ALLOY

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims benefit of United States Patent Provisional application Ser. No. 60/084,688 filed May 8, 1998. All subject matter set forth in provisional application Ser. No. 60/084,688 is hereby incorporated by reference into the present application as if fully set forth herein.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention pertains to a method of preparing alloys. More specifically, the method involves cladding a number of different types of metallic wires in a tubing, drawing the tubing/wires to reduce the diameter thereof, removing the tubing, and heating the remainder so as to form an alloy.

2. Background of the Invention

Various alloys have been studied and utilized in structural materials over pure metals due to the high melting temperature, hardness, and chemical stability of certain alloys. Numerous alloys hold great promise, but are limited by low ductility and low-temperature brittleness. Obtaining these low ductility alloys in wire form is a costly proposition, as once the alloy is formed, is can not we drawn down to wire form.

Alloys are typically formed by powder metallurgy methods or by melt processing of stoichiometric single crystals. Neither of these methods allows for the easy formation of alloy wire, especially where the alloy in demand is of low ductility.

This invention provides a new process for forming wire alloy products from wire precursors. The process involves cladding a number of metallic wires with a tubing to form a composite. At least two types of metal wires are used. The composite is then drawn, stripped of its tubing, and heated so that an alloy forms from the metal precursors. The alloy composition will depend on the composition of the wire precursors.

The present invention is especially useful in that it allows the formation of alloys with normally low ductility into wire form with unexpectedly high ductility.

Nickel aluminides are one type of alloy which can be made by the present invention. Nickel aluminides are intermetallic materials that have long been considered potentially useful due to their strength, hardness, and high melting points. Nickel aluminides are very strong, namely five times as strong as stainless steel. At the same time, alloys are relatively light metals. Standard alloys have a disordered structure that becomes even more random and weaker with increasing temperatures. Nickel aluminides on the other hand, with an ordered structure, becomes stronger with increasing temperature to about 800° C. At high temperatures, they are resistant to wear, deformation, fatigue, and therefore cracking. But nickel aluminides are generally too brittle to be shaped into wire components.

It is therefore an object of the present invention to provide a process for making an alloy in wire form from wire precursors.

It is therefore an object of the present invention to provide a process for making an alloy in a fine fiber form.

It is further an object of the present invention to provide a process for making a wire alloys with unexpectedly high ductilities.

It is further an object of the present invention to provide a process for making an alloy that is economical to manufacture.

The foregoing has outlined some of the more pertinent objects of the present invention. These objects should be construed as being merely illustrative of some of the more prominent features and applications of the invention. Many other beneficial results can be obtained by applying the disclosed invention in a different manner or modifying the invention within the scope of the invention. Accordingly other objects in a full understanding of the invention may be had by referring to the summary of the invention and the detailed description setting forth the preferred embodiment in addition to the scope of the invention defined by the claims taken in conjunction with the accompanying drawings.

SUMMARY OF THE INVENTION

Disclosed is a process for making an alloy. The process comprises cladding with a tube a plurality of metal members to form a metal composite. The metal members include a first and second metal. The metal composite is then drawn to reduce its diameter, and the tubing is then removed from the composite to leave a remainder. The remainder is then heated to convert the metals in the remainder to alloy.

One embodiment involves providing a plurality of first and second metal members comprised of first and second metals respectively and twisting the plurality of metal members into a twisted assembly. A plurality of these assemblies are then jacketed with a composite tube so as to form the metal composite.

In another embodiment, the plurality of metal members is comprised of nickel and aluminum, and each individual metal member is comprised of either nickel or aluminum. The nickel to aluminum weight percentage ration may be 75:25.

The plurality of metal members can be comprised of at least three metals, each individual member being comprised of a single metal. In this embodiment, the plurality of metal members is comprised of aluminum and nickel, and the third metal is selected from the group of metals consisting of boron, chromium, titanium, platinum, and iron.

In a preferred embodiment, the tube cladding the plurality of metal members is comprised of stainless steel.

Another embodiment of the present invention provides a process for making an alloy wherein the first step involves cladding a plurality of metal wires with a plurality of tubings to form a plurality of metal members. The wires are comprised of a first metal, and the tubings of a second. The plurality of metal members are then jacketed with a second tubing to provide a metal composite. The composite is drawn to reduce its diameter, and the second tubing is removed to leave a remainder. The remainder is then heated so as to convert the remainder to an alloy of the first and second metal. Either the metal wires or the metal member first tubings can be comprised of Ni and the other of Al; further the second tubing can be comprised of carbon steel.

Another embodiment provides for a process for making an alloy comprising cladding a plurality of metal wires comprised of a first metal with a plurality of first tubings. The plurality of first tubings comprise a second metal to form a plurality of metal members. Each of the metal member is clad with a second tubing to form a plurality of coated metal members. The coated metal members were drawn to reduce the diameter thereof. The plurality of coated metal members are clad with a third tubing to provide a metal composite. The metal composite is drawn to reduce the diameter thereof. The second and third tubings are removed to provide a metallic remainder comprising the metallic first tubing cladding material with the metallic wire material. The metallic remainder is heated to convert the metallic remainder to alloy. In this embodiment, the alloy product can be fibrous.

The foregoing has outlined rather broadly the more pertinent and important features of the present invention in order that the detailed description that follows may be better understood so that the present contribution to the art can be more fully appreciated. Additional features of the invention will be described hereinafter which form the subject of the claims of the invention. It should be appreciated that the conception and the specific embodiments disclosed may be readily utilized as a basis for modifying or designing other structures for carrying out the same purposes of the present invention. It also should be realized by those skilled in the art that such equivalent constructions do not depart from the spirit and scope of the invention as set forth in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

For a fuller understanding of the nature and objects of the invention, reference should be made to the following detailed description taken in connection with the accompanying drawings in which:

FIG. **1** is a block diagram illustrating a general process **10** for creating an alloy;

FIG. **2** is an isometric view of a metal wire;

FIG. **2**A is an enlarged cross sectional view of FIG. **2**;

FIG. **3** is an isometric view of the metal wire referred to in FIG. **2** encased in a tube to thereby form a metal member;

FIG. **3**A is an enlarged cross-sectional view of FIG. **3**;

FIG. **4** is an isometric view of a plurality of metal members jacketed or inserted within a composite tube;

FIG. **4**A is a cross sectional view of FIG. **4**;

FIG. **5** is an isometric view of the plurality of the metal members inserted within the preformed tube after the process step of drawing the metal composite;

FIG. **5**A is an enlarged end view of FIG. **5**;

FIG. **6** is an isometric view illustrating the mechanical removal of the preformed composite tube;

FIG. **6**A is an enlarged end view of FIG. **6**;

FIG. **7** is an isometric view illustrating the remainder upon complete removal of the tube;

FIG. **7**A is an enlarged cross sectional view of the alloy product of the heated remainder of FIG. **7**;

FIG. **8** is an isometric view of a metal wire;

FIG. **8**A is an enlarged cross sectional view of FIG. **8**;

FIG. **9** is an isometric view of the metal wire referred to in FIG. **8** encased in a tube to thereby form a metal member;

FIG. **9**A is an enlarged cross-sectional view of FIG. **9**;

FIG. **10** is an isometric view of the metal member referred to in FIG. **9** encased in a member coating tube to thereby form a coated metal member;

FIG. **10**A is an enlarged cross-sectional view of FIG. **10**;

FIG. **11** is an isometric view of a plurality of coated metal members jacketed or inserted within a composite tube;

FIG. **11**A is a cross sectional view of FIG. **11**;

FIG. **12** is an isometric view of the plurality of the coated metal members inserted within the preformed composite tube after the process step of drawing the metal composite;

FIG. **12**A is an enlarged end view of FIG. **12**;

FIG. **13** is an isometric view of a remainder after the member coating the tubing and composite tubing have been removed;

FIG. **13**A is an enlarged cross sectional view of a remainder lacking the composite tubing and coated member tubing;

FIG. **14** is an isometric view illustrating the remainder upon complete removal of the tube;

FIG. **14**A is a cross sectional view of FIG. **14**;

FIG. **15** is an isometric view of the alloy product of the heated remainder of FIG. **14**.

FIG. **15**A is a cross sectional view of FIG. **15**;

FIG. **16** is an isometric view of a first metallic wire;

FIG. **16**A is an end view of FIG. **16**;

FIG. **17** is an isometric view of an assembly (metal member) of first and second plurality of coated wires;

FIG. **17**A is an end view of FIG. **17**;

FIG. **18** is an isometric view of a jacketed array of the assemblies or metal members comprised of the first and second wires of FIG. **17**;

FIG. **18**A is a cross sectional view of the metal composite or cladding of FIG. **18**;

FIG. **19** is an isometric view of the metal composite of FIG. **18** after a first drawing process;

FIG. **19**A is an end view of FIG. **19**;

FIG. **20** is an isometric view illustrating the mechanical removal of the composite tube;

FIG. **20**A is an enlarged cross sectional view of FIG. **20**;

FIG. **21** is an isometric view illustrating the remainder upon complete removal of the tube;

FIG. **21**A is an enlarged cross sectional view of FIG. **21** after heating, showing the alloy product of the heated remainder of FIG. **21**;

FIG. **22** is an isometric view of another example of an assembly metal member comprised of a plurality of first and second metallic wires;

FIG. **23** is an isometric view of another example of an assembly member of a plurality of first and second metallic wires;

FIG. **24** is an isometric view of a plurality of arranged wires that have been twisted so as to form a twisted metal member; and

FIG. **25** is an isometric view of another example of an arrangement of first and second wires into a metal member wherein each metal member is jacketed in a tubing and a plurality of jacketed metal members will then be jacketed in a composite tubing to comprise the metal composite.

DETAILED DISCUSSION

The present invention is unique in that it provides a new method for creating alloys, and more specifically provides a new method for creating alloys with high ductility that by other methods would have a low ductility.

FIG. **1** is a block diagram illustrating a general process **10** for creating an alloy. The process **10** of FIG. **1** comprises cladding a plurality of at least two types of metal members with a tube. Each metal member, can have any number take a number of forms, including a metal wire form, a metal coated wire form, a multiple coated wire form, a drawn metal coated wire form, or a drawn multiple coated wire form. The metal members may have varied diameters. The at least two types of metal members are comprised of different metals. A plurality of metal members are jacketed with tubing to form a metal composite. This metal composite is then drawn to reduce the diameter of the composite. The tube and optionally any number of the metal coatings are then removed, physically and/or chemically, and the remainder is then heated to convert the remainder to alloy.

In a first general embodiment of the present invention, the metal members are comprised of a wire that is jacketed by a tubing, and a plurality of these metal members are then jacketed by a second tubing to form a metal composite.

FIG. **2** is an isometric view of a metal wire **20**, with FIG. **2**A being an enlarged cross sectional view of FIG. **2**. The metal wire has a diameter **20**D.

Preferably, the wire is made of a metal selected from the group of aluminum, nickel, iron, and titanium, although any metal wire may be used. The wire may be comprised of an alloy. In one preferred embodiment, the wire is comprised of an aluminum boron alloy, or a nickel chromium alloy.

FIG. **3** is an isometric view of the metal wire **20** referred to in FIG. **2** encased in a tube **30** to thereby form a metal member **31** referred to in FIG. **1**. The tube **30** is comprised of a different metal than the metal wire **20**. Preferably, the tubing is comprised of a metal selected from the group of aluminum, nickel, iron and titanium although any metal can be used. The tube **30** may be comprised of an alloy. In a preferred embodiment, the alloy is selected from a nickel-chromium alloy or an aluminum-boron alloy. The tube **30** has an outer diameter **30**D. FIG. **3**A is an enlarged cross-sectional view of FIG. **3**.

FIG. **1** illustrates the process step **12** of cladding a plurality of metal members **20** with a tube **40**. FIG. **4** is an isometric view of a plurality of metal members **20** jacketed or inserted within a composite tube **40** with FIG. **4**A being a cross sectional view of FIG. **4**. In this embodiment of the invention, the composite tube **40** is a preformed tube. Preferably, the preformed composite tube **40** is made of a carbon steel material.

The plurality of metal members **31** are assembled in an array **50**. The array **50** of the plurality of metal members **31** are jacketed within the tube **40** for providing a metal composite **60** having a diameter **60**D.

Although the composite tube **40** is disclosed as a preformed carbon steel tube, the array **50** of the plurality of metal members **20** may be encased within the tube **40** through a conventional cladding process. Preferably, approximately one thousand (1000) metallic members **31** are inserted within the composite tube **40**.

FIG. **1** illustrates the process step **13** of drawing the metal composite **60**. The process step **13** of drawing the metal composite **60** provides three effects. Firstly, the process step **13** reduces an outer diameter **60**D of the metal composite **60**. Secondly, the process step **13** reduces the corresponding outer diameter **20**D of each of the plurality of metal wires **20** and the corresponding outer diameter **30**D of each of the wire tubings **30**. Thirdly, the process step **13** causes the coating materials **30** on each of metal wires **20** to diffusion weld with the tubings **30** cladding adjacent metallic wires **20**.

The drawing procedure may by performed more than once to draw the metal composite down to a desired diameter. This is necessary to control the amount of heat generated in the drawing process, which could prematurely cause the wire and tubing metals to react to form an alloy.

FIG. **5** is an isometric view of the plurality of the metal members **31** inserted within the preformed tube **40** after the process step **13** of drawing the metal composite **60**. FIG. **5**A is an enlarged end view of FIG. **5**. Drawing the metal composite **60** causes the tubing **30** on each metal wire **20** to diffusion weld with the tubing **30** on adjacent metal wires **20**. The diffusion welding of the cladding tubings **30** on adjacent metal wires **20** forms a unitary cladding material **70** that extends throughout the interior of the metal composite **60**. The plurality of metal wires **20** are contained within the unitary cladding material **70** extending throughout the interior of the metal composite **60**.

FIG. **1** illustrates the process step **14** of removing the composite tube **40**. In the preferred form of the process, the step **14** of removing the composite tube **40** comprises mechanically removing the composite tube **40**.

FIG. **6** is an isometric view illustrating the mechanical removal of the preformed composite tube **40** with FIG. **6**A being an enlarged end view of FIG. **6**. In one example of this process step **14**, the composite tube **40** is scored or cut at **71** and **72** by mechanical scorers or cutters (not shown). The scores or cuts at **71** and **72** form composite tube portions **73** and **74** that are mechanically pulled apart to peel the composite tube **40** off of the metal composite **60** to leave a remainder **80**. Alternatively, the composite tube can be chemically removed from the composite to leave a remainder **80**.

FIG. **1** illustrates the process step **15** of heating the composite tube **40** minus the composite tubing **40** to convert the remainder to alloy. In the preferred form of the process, the remainder **80** is heated to a temperature in the range of 1000° C.–1300° C. step **15** so as to convert the metal remainder **80** to an alloy.

FIG. **7** is an isometric view illustrating the remainder **80** upon complete removal of the tube **40**. The remainder **80** comprises substantially unitary cladding material **70** with the plurality of metallic wires **20** contained therein. The remainder **80** defines an outer diameter **80**D. The spiraling arrows represent the general application of heat to the remainder **80**. As heat is applied to the remainder **80**, the metals of the unitary cladding material and the metal wires combine to form a new metal alloy **90**.

FIG. **7**A is an enlarged cross sectional view of the alloy product **90** of the heated remainder **80** of FIG. **7**. The alloy **90** is a single strand product. The product has a high ductility.

In a preferred embodiment, the alloy is Ni_3Al. In this embodiment, the metal wire diameter and composite tubing thickness (one comprised of nickel and the other of aluminum) are chosen so that the final product contains seventy-five atomic percent Ni and twenty-five atomic percent Al. The reactants must have roughly 86.7% by weight nickel and 13.3% by weight aluminum. The alloy product has a number of randomly oriented pores **92** which can be attributed to the lower density of Ni_3Al in comparison to the densities of nickel or aluminum alone. The product has a high ductility for an alloy of normally low ductility.

In another embodiment, the alloy product is NiAl. In this embodiment, the metal wire diameter and composite tubing thickness are chosen so that the final product contains fifty atomic percent Ni and fifty atomic percent Al.

In yet another embodiment, the alloy product is Fe_3Al. The metal wire diameter and composite tubing thickness (one comprised of iron and the other of aluminum) are chosen so that the final product contains seventy-five atomic percent Fe and twenty-five atomic percent Al.

In another embodiment, the alloy product is FeAl. In this embodiment, the metal wire diameter and composite tubing thickness are chosen so that the final product contains fifty atomic percent Fe and fifty atomic percent Al.

FIG. **8** is an isometric view of a metal wire **120**, with FIG. **8**A being an enlarged cross sectional view of FIG. **8**. Preferably, the wire is made of a metal selected from the group of aluminum, nickel, chromium, iron, stainless steel, titanium, platinum, and boron, although any metal wire may be used. The wire may be comprised of an alloy. In a preferred embodiment, the wire is comprised of an aluminum boron alloy, or a nickel chromium alloy. The metal wire has a diameter **120**D.

FIG. **9** is an isometric view of the metal wire **120** referred to in FIG. **8** encased in a tube **130** to thereby form a metal member **131**. The tube **130** is comprised of a different metal than the metal wire **120**. Preferably, the tubing **131** is comprised of a metal selected from the group of aluminum, nickel, iron and titanium, although any metal can be used. The tube **130** may be comprised of an alloy. In a preferred embodiment, the alloy is selected from a nickel-chromium alloy or an aluminum-boron alloy. The tube **130** has an outer diameter **130**D. FIG. **9**A is an enlarged cross-sectional view of FIG. **9**.

FIG. **10** is an isometric view of the metal member **131** referred to in FIG. **9** encased in a member coating tube **134** to thereby form a coated metal member **136**. FIG. **10**A is an enlarged cross-sectional view of FIG. **10**. The member coating tube **134** is comprised of a different metal than the tubing that jackets the metal wires **130**. Preferably, the tubing **134** is made of carbon steel. Alternatively, the member coating tube **134** is comprised of a metal selected from the group of aluminum, nickel, iron and titanium, although any metal can be used. The tube **134** may be comprised of an alloy. In a preferred embodiment, the alloy is selected from a nickel-chromium alloy or an aluminum-boron alloy. The tube **134** has an outer diameter **134**D.

FIG. **1** illustrates the process step **12** of cladding a plurality of metal members with a tube. However, in this embodiment, a plurality of coated metal members **136** are jacketed with a tube to form a metal composite **160**. FIG. **11** is an isometric view of a plurality of coated metal members **136** jacketed or inserted within a composite tube **140** with FIG. **11**A being a cross sectional view of FIG. **11**. In the diagramed embodiment of the invention, the composite tube **140** is a preformed tube. Preferably, the preformed composite tube **140** is made of a carbon steel material.

The plurality of coated metal members **136** are assembled in an array **150**. The array **150** of the plurality of coated metal members **136** are jacketed within the tube **140** for providing a metal composite **160** having a diameter **160**D.

Although the composite tube **140** is disclosed as a preformed carbon steel tube, the array **150** of the plurality of coated metal members **136** may be encased within the tube **140** through a conventional cladding process. Preferably, approximately one thousand (1000) coated metallic members **136** are inserted within the composite tube **140**.

FIG. **1** illustrates the process step **13** of drawing the metal composite. The process step **13** of drawing the metal composite **160** provides three effects. Firstly, the process step **13** reduces an outer diameter **160**D of the metal composite **160**. Secondly, the process step **13** reduces the corresponding outer diameter **120**D of each of the plurality of metal wires **120** and the corresponding outer diameter **130**D, **134**D of each of the wire coating tubings **130**, **134**. Thirdly, the process step **13** causes the member coating tube **134** materials on each of the coated metal members **136** to diffusion weld with the tubing **134** material of adjacent coated metal members **136**.

The drawing procedure may by performed more than once to draw the metal composite down to a desired diameter. This is necessary to control the amount of heat generated in the drawing process, which could prematurely cause the wire and tubing metals to react to form an alloy.

FIG. **12** is an isometric view of the plurality of the coated metal members **136** inserted within the preformed composite tube **140** after the process step **13** of drawing the metal composite **160**. FIG. **12**A is an enlarged end view of FIG. **12**.

FIG. **1** illustrates the process step **14** of removing the composite tube. In the preferred form of the process, the step **14** of removing the composite tube comprises mechanically removing the composite tube. In the present embodiment, where a plurality of wires is double jacketed prior to being jacketed into a metal composite, the composite tubing **140** may be removed either mechanically or chemically, as described above, thereby leaving a remainder **180**.

In a preferred embodiment, both the composite tubing **140** and the member coating tubing **134** is comprised of carbon steel, and ultimately both components are removed from the remainder **180**. In this embodiment, the composite tubing **140** can be removed either mechanically or chemically, but the coated member tubing must be removed chemically. It is preferred that both be removed chemically. Where a metal utilized in a wire **120**, tubing **130**, or member coating tubing **134** is leached out, the drawn composite can be cut in segments to increase the efficiency of the chemical leaching process.

In an embodiment where the member coating tubing and the composite tubing have been removed from the metal composite **160**, the resulting remainder is a fibrous product, as demonstrated in FIGS. **13** and **13**A. FIG. **13**A is an enlarged cross sectional view of a remainder lacking the composite tubing and coated member tubing. The remainder **180** basically consists of a plurality of metal members **131** (comprised of the initial metal wire and surrounding tubing) running essentially in parallel. One manifestation of this embodiment exists where the composite tubing **140** and member coating tubing **134** are comprised of carbon steel.

FIG. **1** illustrates the process step **15** of heating the composite **140** minus the composite tubing **140** to convert the remainder to alloy. In the preferred form of the process, the remainder **180** is heated to a temperature in the range of 1000° C.–1300° C. step **15** so as to convert the metal remainder **180** to an alloy.

FIG. **14** is an isometric view illustrating the remainder **180** upon complete removal of the tube **40**. The remainder **180** comprises substantially a plurality of tightly packed metal members **131** running substantially in parallel. The remainder **80** defines an outer diameter **80**D. The spiraling arrows in FIG. **14** represent the general application of heat to the remainder **180**. As heat is applied to the remainder **180**, the metals in each metal member **131** (from the metal wire **120** and the tubing **130**) combine to form a new metal alloy **190**. FIG. **14**A is a cross sectional view of FIG. **14**.

FIG. **15**A is a cross sectional view of FIG. **15** and is an enlarged cross sectional view of the alloy product **190** of the heated remainder **180** of FIG. **7**. The alloy **190** product is comprised of a plurality of fibers running in parallel **194**. The product has a high ductility.

In a preferred embodiment, the alloy is Ni_3Al. In this embodiment, the metal wire diameter and composite tubing thickness (one comprised of nickel and the other of aluminum) are chosen so that the final product contains seventy-five atomic percent Ni and twenty-five atomic percent Al. The reactants must be roughly 86.7% by weight nickel and 13.3% by weight aluminum. The member coating and composite tubing, both removed either mechanically or chemically, are comprised of carbon steel. The alloy product is fibrous in nature. Each fiber has a number of randomly oriented pores which can be attributed to the lower density of Ni_3Al in comparison to the densities of nickel or aluminum alone. The product has a high ductility for an alloy of normally low ductility.

In another embodiment, the alloy product is NiAl. In this embodiment, the metal wire diameter and composite tubing thickness are chosen so that the final product contains fifty atomic percent Ni and fifty atomic percent Al. Again the member coating tubing and composite tubing, both removed either mechanically or chemically, are comprised of carbon steel.

In yet another embodiment, the alloy product is Fe_3Al. The metal wire diameter and composite tubing thickness (one comprised of iron and the other of aluminum) are chosen so that the final product contains seventy-five atomic percent Fe and twenty-five atomic percent Al. The member coating and composite tubings are removed.

In another embodiment, the alloy product is FeAl. In this embodiment, the metal wire diameter and composite tubing thickness are chosen so that the final product contains fifty atomic percent Fe and fifty atomic percent Al. Again, the member coating and composite tubings are removed.

In a third embodiment of the present invention, a metal member is comprised of a metal wire, and a plurality of these metal wires are jacketed with a tubing to form a metal composite that is drawn, stripped of its cladding, and heated to form an alloy. A plurality of two types of wire of different composition are encased in a tube to form a metal composite. The tubing has a different metal composition than the two types of wires, although if three wire types are used, the tubing may have the same composition as one of the wire types. In a preferred embodiment, the tubing is comprised of carbon steel. After the plurality of wires are encased in the tubing, the resulting metal composite is drawn to a decreased diameter. The outer tube is then removed, either mechanically or chemically, and the remainder is heated at a temperature that will convert the remaining metal wires to an alloy. Where more than two types of wire are jacketed, one of the wire types may be removed from the composite contemporaneously or separately from the cladding tube removal.

In a slightly more elaborate sub-embodiment, a metal member is comprised of an arrangement of at least two types of wires into an assembly, and a plurality of these metal members (assemblies of wires) are jacketed to form a composite which is then drawn, stripped of its cladding, and heated to conversion to alloy.

FIG. **16** is an isometric view of a first metallic wire **222** with a diameter **222**. FIG. **16**A is an end view of FIG. **16**. FIG. **17** is an isometric view of the first metallic wire **222** and a plurality of second metallic wires **221** which are assembled to form an assembled metallic member **231**. The assembly metal member **231** comprises a arrangement of the first and second metallic wires **221** and **222**. In the example, each of the plurality of first metallic wires **221** has first diameter **221**D whereas the second metallic wire **222** has second diameter **222**D. In the illustrated embodiment, the first diameter **221**D of the first metallic wire **221** is smaller in diameter relative to the second diameter **222**D of the second metallic wire **222**. As will be described in greater detail hereinafter, the assembly metal member **231** may be formed in various ways. FIG. **17**A is a cross sectional view of FIG. **17**.

In a preferred embodiment, the first and second wires have the same diameter, and the metal members are comprised of nickel and aluminum in a ratio of six nickel wires to one aluminum wire. In another embodiment, the metal members are comprised of nickel and aluminum wires in a ratio of five nickel to two aluminum wires.

FIG. **1** illustrates the process step **12** of cladding an array of assemblies or metal members within the tube to form the metal composite or cladding.

FIG. **18** is an isometric view of a jacketed array **250** of the assemblies or metal members **231** comprised of the first and second wires **221** and **222** of FIG. **16**. FIG. **18**A is a cross sectional view of the metal composite or cladding of FIG. **18**. The composite cladding tube **240** has a diameter **240**D. The composite cladding tube **240** can act as a heat sink to protect the array **250** of member assemblies **231** of the first and second plurality of (coated) wires **221** and **222** from the heat of the drawing process, thereby preventing premature alloy formation. Where the wires are jacketed prior to being arranged into the assembly metal members, the wire tubing material **230**A, **230**B is preferably of the same material as the composite cladding tubing **240**.

Preferably, the composite cladding tube **240** is a carbon steel material with the plurality of first and second metallic wires **221** and **222** being made of nickel and aluminum. Preferably, approximately one thousand (1000) of the first and second metallic wires **221** and **222** are encased within the casing **234**.

In a preferred embodiment, the metal members comprised of the arrangement of metal wires can be drawn and then jacketed with a tubing prior to being jacketed with a composite tube to form a metal composite.

FIG. **1** illustrates the process step **13** of drawing the metal composite to reduce the diameter thereof. FIG. **19** is an isometric view of the metal composite of FIG. **18** after a first drawing process **13**. The composite may be drawn more than once. FIG. **19**A is an end view of FIG. **19**. The process step **13** of drawing the metal composite **260** provides three effects. Firstly, the drawing step **13** reduces the outer diameter **260**D of the composite **260**. Secondly, the drawing step **13** reduces the corresponding outer diameter **221**D and **222**D of each of the first and second plurality of metallic wires **221** and **222** and, when coated, the corresponding outer diameter **230**A-D and **330**B-D of each of the coating materials **230**A and **230**B. Thirdly, the heat generated in the drawing step **13** can cause the adjacent like wires within a metal member to diffusion weld and the like wires of adjacent metal members to become continuous. This is the case where the wires are comprised of nickel, or are comprised of aluminum.

FIG. **1** illustrates the process step **14** of removing the composite tube to leave a remainder. Preferably, the step **14** of removing the tube comprises mechanically removing the tube.

FIG. **20** is an isometric view illustrating the mechanical removal of the composite tube **240** with FIG. **20**A being an enlarged cross sectional view of FIG. **20**. In one example of this process step, the tube **240** is scored or cut at **271** and **272** by mechanical scorers or cutters (not shown). The scores or cuts at **271** and **272** form tube portions **273** and **274** that are mechanically pulled apart to peel the tube **240** off of a remainder **280**. The remainder **280** comprises a substantially unitary material **270** with the first and second plurality of metallic wires **221** and **222** contained therein. The remainder **280** defines an outer diameter **280**D.

FIG. **1** illustrates the process step **15** of heating the composite minus the composite tubing to convert the remainder to alloy. In the preferred form of the process, the remainder is heated to a temperature in the range of 1000° C.–1300° C. step **15** so as to convert the metal remainder to an alloy.

FIG. **21** is an isometric view illustrating the remainder **280** upon complete removal of the tube **240**. The remainder **280** comprises substantially continuous metal phase of metal wire **221** material with metal mire **222** dispersed throughout. The remainder **280** defines an outer diameter **280**D. The spiraling arrows in FIG. **21** represent the general application of heat to the remainder **280**. As heat is applied to the remainder **280**, the metals in each metal member **231** (from the metal wires **220**, **222**) combine to form a new metal alloy **290**.

FIG. **21**A is an enlarged cross sectional view of FIG. **21** after heating, showing the alloy product **290** of the heated remainder **280** of FIG. **21**. The alloy **290** product is comprised of a single wire. The wire has a number of randomly oriented pores which presumable form due to the difference in density of the product and the pre-alloy metals. The product has a high ductility.

In a preferred embodiment, the alloy is Ni_3Al. In this embodiment, the metal wire diameter and composite tubing thickness (one comprised of nickel and the other of aluminum) are chosen so that the final product contains seventy-five atomic percent Ni and twenty-five atomic percent Al. The reactants must have roughly 86.7% by weight nickel and 13.3% by weight aluminum.

In another embodiment, the alloy product is NiAl. In this embodiment, the metal wire diameter and composite tubing thickness are chosen so that the final product contains fifty atomic percent Ni and fifty atomic percent Al. Where the diameter of the aluminum and nickel (first and second) wires is the same, the ration of nickel wires to aluminum wires in a given metal member is 5:2.

In yet another embodiment, the alloy product is Fe3Al. The metal wire diameter and composite tubing thickness (one comprised of iron and the other of aluminum) are chosen so that the final product contains seventy-five atomic percent Fe and twenty-five atomic percent Al.

In another embodiment, the alloy product is FeAl. In this embodiment, the metal wire diameter and composite tubing thickness are chosen so that the final product contains fifty atomic percent Fe and fifty atomic percent Al.

FIG. **22** is an isometric view of another example of an assembly metal member comprised of a plurality of first and second metallic wires **421** and **422**. The first metallic wires **421** have a first diameter **421**D whereas the second metallic wires **422** have a second diameter **422**D. In addition, the first metallic wires may be of a different composition than the second metallic wire **422**. The first and second metallic wires **421** and **422** form a mixed assembly suitable for use as the assembly members **431** set forth in FIGS. **18–21**. In this example, the first and second metallic wires **421** and **422** are randomly located within the assembly metal member **431**.

FIG. **23** is an isometric view of another example of an assembly member **531** of a plurality of first and second metallic wires **521** and **522**. As shown, the first metallic wires **521** have a first diameter **521**D whereas the second metallic wires **522** have a second diameter **522**D. In this example, the ratio of the first and second metallic wires **521** and **522** is altered relative to the assembly of FIG. **18**.

In addition, the plurality of first and second and third metallic wires **621**,**622**, **623** can be twisted to form a twisted assembly metal member **631** (FIG. **24**). A plurality of these twisted assembly metal members are assembled into an array for cladding into a composite tube to form a metal composite. This twisting can be performed on any of the aforementioned assembly metal members. Preferably, the first, second, and third metallic wires **621**, **622**, and **623** are twisted into a helical pattern to provide the metal member **631** at the rate of 1.5 turns per 2.5 centimeters. The metal members may be coiled for on a spool (not shown) for temporary storage.

FIG. **25** is an isometric view of another example of an arrangement of first and second wires into a metal member. In this example of an array, each metal member **731** is jacketed in a tubing **732**, and a plurality of jacketed metal members **731** will then be jacketed in a composite tubing to comprise the metal composite. Preferably the tubing **732** that jackets each individual metal member **731** and the composite tubing (not shown) are comprised of the same metal, most preferably carbon steel. When the composite tubing is removed (mechanically or chemically), the tubings surrounding the first and second wires are either contemporaneously or separately removed (chemically) to leave a remainder **780**. Once heated, the remainder converts to a fibrous alloy product **790**. Again, some of the preferred alloy products include Ni_3Al, NiAl, Fe_3Al, and FeAl. Other metal wires can be used to produce other wire alloy products. Any number of the metal wires can be alloy.

The present disclosure includes that contained in the appended claims as well as that of the foregoing description. Although this invention has been described in its preferred form with a certain degree of particularity, it is understood that the present disclosure of the preferred form has been made only by way of example and that numerous changes in the details of construction and the combination and arrangement of parts may be resorted to without departing from the spirit and scope of the invention.

What is claimed is:

1. A process for making an alloy comprising:

a. cladding with a tube a plurality of metal wire members including a first and a second metal to form a metal composite;

b. drawing the metal composite for reducing the diameter thereof;

c. removing the tube so as to provide a remainder; and

d. heating the remainder to a temperature sufficient to convert the first metal and the second metal within the remainder to form the alloy from the first metal and the second metal.

2. The process for making an alloy as defined in claim **1**, further comprising providing a plurality of first and second metal members comprised of first and second metals respectively and twisting the plurality of metal members into a twisted assembly, and cladding with a composite tube a plurality of the twisted assemblies so as to form the metal composite of step (a).

3. The process for making an alloy as defined in claim **1**, wherein the plurality of metal members is comprised of nickel and aluminum, and wherein each individual metal member is comprised of either nickel or aluminum.

4. The process for making an alloy as defined in claim **3**, wherein the nickel to aluminum ratio in atoms is 3 to 1.

5. The process for making an alloy as defined in claim **1**, wherein the plurality of metal members is comprised of at least three metals, and wherein each individual member is comprised of a single metal.

6. The process for making an alloy as defined in claim **5**, wherein the plurality of metal members is comprised of aluminum and nickel, and wherein the plurality of metal members further comprises at least one of the metals selected from the group consisting of Ti and Fe.

7. The process for making an alloy as defined in claim **1**, wherein the tube cladding the plurality of metal members is comprised of carbon steel.

8. The process for making an alloy as defined in claim **1**, further including the step of cladding a plurality of metal wires comprised of a first metal with a plurality of second tubings comprised of a second metal by placing a tubing on each metal wire to form the plurality of metal members of step (a).

9. The process for making an alloy as defined in claim **8**, further comprising drawing the plurality of metal members to reduce the diameter thereof prior to cladding the metal members to form the metal composite.

10. The process for making an alloy as defined in claim **8**, wherein either one of the metal rod members or the metal member second tubing is comprised of Ni and wherein the other is comprised of Al.

11. The process for making an alloy as defined in claim **1**, further including the steps of cladding a plurality of metal wires comprised of a first metal with a plurality of second tubings comprised of a second metal by placing a tubing to form a plurality of metal members;

cladding the metal members with a third tubing to form a plurality of coated metal members;

drawing the coated metal members to reduce the diameter thereof;

cladding with a tube the plurality of coated metal members with the tube of step (a) to form the metal composite of step (a); and

removing the third tubing in step (c) as well as the outer tube of the metal composite to provide the metallic remainder.

12. A process for making an alloy comprising:

a. cladding a plurality of metal wires comprised of a first metal with a plurality of first tubings comprised of a second metal to form a plurality of metal members;

b. cladding the plurality of metal members with a second tubing to provide a metal composite;

c. drawing the metal composite to reduce the diameter thereof to provide a drawn metal composite;

d. removing the second tubing to provide a metal remainder comprising the metal first tubing cladding material with the metal wire material contained therein; and

e. heating the remainder to a temperature sufficient to convert the first metal and the second metal within the remainder to form the alloy from the first metal and the second metal.

13. The process for making an alloy as defined in claim **12**, wherein the drawn metal composite is heated subsequent to removing the second tubing.

14. The process for making an alloy as defined in claim **12**, wherein either the metal wires or the metal member first tubings are comprised of Ni and wherein the other is comprised of Al.

15. The process for making an alloy as defined in claim **13**, wherein the second tubing is comprised of carbon steel.

16. The process for making an alloy as defined in making an alloy as defined in claim **12**, including the step of cladding each metal member with a third tubing to form a plurality of coated metal members;

drawing the coated metal members to reduce the diameter thereof; cladding the plurality of coated metal members with the second tubing of step (b) to form the metal composite of step (b); and

additionally removing the third tubing along with the second tubing in step (d) to provide the metallic remainder.

17. The process for making an alloy as defined in claim **16**, wherein said metal remainder is in fibrous form.

18. A process for making an alloy comprising:

a. cladding a plurality of metal wires comprised of a first metal with a plurality of first tubings comprised of a second metal to form a plurality of metal members;

b. cladding each metal member with a second tubing to form a plurality of coated metal members;

c. drawing the coated metal members to reduce the diameter thereof;

d. cladding the plurality of coated metal members with a third tubing to provide a metal composite;

e. drawing the metal composite to reduce the diameter thereof;

f. removing the second and third tubings to provide a metallic remainder comprising the metallic first tubing cladding material with the metallic wire material; and

heating the remainder to a temperature sufficient to convert the first metal and the second metal within the remainder to form the alloy from the first metal and the second metal.

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